Radiological Health Data and Reports

VOLUME 11, NUMBER 9

SEPTEMBER 1970

(Pages 421-486)

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service • Environmental Health Service

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	jĭ'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	kĭl'o
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn'ti
10^{-3}	milli	m	mĭl'i
10^{-6}	micro	μ	mi'kro
10^{-9}	nano	n	năn'o
10^{-12}	pico	p	pē'ko
10^{-15}	femto	f	fĕm'to
10^{-18}	atto	a	ăt'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.205 lb.
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/mi^2
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 11, Number 9, September 1970

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the Bureau of Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the Bureau of Radiological Health by Federal agencies, State health departments, universities, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

Department of Defense
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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
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Bureau of Radiological Health

Reports

Tritium in Streams in the United States, 1961-1968

T. A. Wyerman,[1] *R. K. Farnsworth,*[2] and *G. L. Stewart*[3]

As part of its program of water resources investigations, the U.S. Geological Survey has been analyzing the tritium content of stream water since the early 1960's. The results of this sampling program for 20 streams in the conterminous United States and Alaska are tabulated along with relevant stream discharge data. The data show the effect on stream tritium concentration caused principally by thermonuclear detonations, and also seasonal, latitudinal, and continental effects.

Before the first thermonuclear device was tested in 1952, tritium was very scarce in natural waters (*1–4*). Natural tritium is largely created by the bombardment of nitrogen in the upper atmosphere by nuclear particles in cosmic radiation. Subsequent oxidation of the tritium (T) leads to the tritiated water molecule (HTO) which eventually reaches the earth's surface in precipitation.

Because the rate of production of natural tritium in the atmosphere is believed to be relatively constant and the tritium decay rate of 5.5 percent (*5*) per year is constant, a worldwide equilibrium in tritium in the hydrologic cycle was in effect prior to 1952. Before hydrologic studies were set up to measure and utilize the distribution of natural tritium in the hydrologic cycle, the detonation of thermonuclear devices yielded large quantities of artificial tritium to the atmosphere and upset the equilibrium. Consequently, the hope for the hydrologic use of tritium shifted from a hydrologic cycle generally in equilibrium with natural tritium to one thrown out of equilibrium by large irregular input pulses of artificial tritium.

At the earth's surface, precipitation generally gives the first indication of artificial tritium input to the hydrologic cycle by thermonuclear explosions. There has been an irregular rise and fall in tritium concentration in precipitation due directly to thermonuclear explosions, especially in the Northern Hemisphere. For instance, at Chicago, the tritium concentration in precipitation increased from about 32 pCi/liter[4] before 1954, to a maximum of approximately 12,800 pCi/liter in 1963, and then declined to about 320 pCi/liter in 1968. Superimposed on this long-term rise and fall in tritium concentration are short seasonal and annual variations and latitude and continental effects (*6–7*). The effects of these variations of tritium in precipitation upon the tritium concentration of streams in the United States during 1961–1968 are the basis for this report.

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[4] One picocurie per liter equals 2.22 disintegrations per minute per liter and 0.3083 tritium units. One tritium unit is one tritium atom in 10^{18} hydrogen atoms.

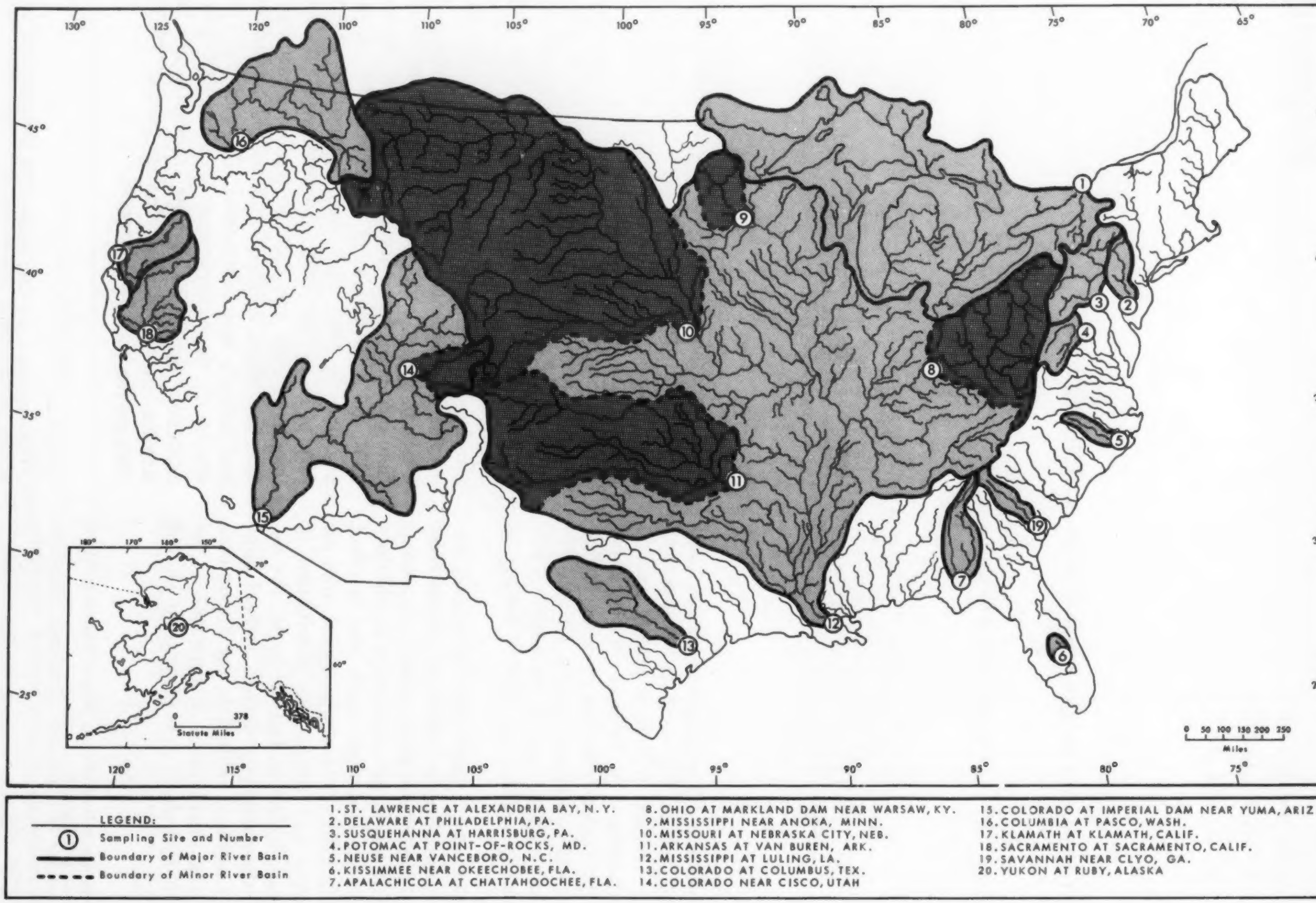

Figure 1. Stream tritium sampling locations in continental United States

The network

In 1963, the U.S. Geological Survey began a routine sampling program on streams to determine the tritium concentration of surface water in the continental United States. Before 1963, stream sampling for this purpose was irregular. In 1964 and 1965, the sampling network was expanded to include eight more streams, but the station on one of these streams, the St. Lawrence River, was discontinued in 1967. The accompanying tables present the results of all analyses of network stream samples received in the tritium laboratory to the end of 1968. Figure 1 shows the basins and sampling locations of all the streams sampled, except for the Yukon River at Ruby, Alaska.

Sampling procedure

Stream samples of 50 to 1,000 milliliters were collected by personnel of the U.S. Geological Survey at or near gauging stations where stream discharge data are collected. Where a specific date of sampling is shown in the tables, the sample was a single grab sample collected on that date. Where a month only is shown, the sample consisted of a composite of daily, weekly, or biweekly grab samples collected during that month. The notation "NS" in the tables indicates that no sample was collected for the period listed; however, the period is included to permit continuity of the discharge record.

Analytical procedures

After samples were received at the laboratory, they were either subjected to tritium counts directly by one of two types of counting systems, or were enriched by electrolysis before counting. The analytical techniques described by Hoffman and Stewart (*8*), were generally applied to the earlier samples; however, improvements in systems and techniques have since been made and adapted to tritium analyses. Presently, if the tritium concentration exceeds about 1,000 pCi/liter, 5 milliliters of the samples are predistilled and counted without enrichment using a model 3003 Packard liquid scintillation spectrometer. The counting solution contains 4 milliliters of water emulsified in 18 milliliters of scintillation solution, which consists of 76 percent (by volume) toluene, 24 percent Triton X-100 (Rohm and Haas) (alkylaryl polyether alcohol), 7 grams per liter of PPO (2,5 diphenyloxazole), and 0.5 grams per liter of POPOP [1,4-bis-2-(phenyloxazolyl)-benzene]. This mixture in a 25-milliliter polyethylene vial yields a counting efficiency for tritium of about 27 percent and a background of about 7.5 counts per minute.

Table 1. Apalachicola River at Chattahoochee, Fla.

Date	Tritium concentration (pCi/liter)	Discharge (m^3/s)	
		Daily	Monthly mean
1964			
November 28	646	753	612
November 29	624	657	—
December 30	691	2,540	1,170
1965			
January 27	720	1,512	1,103
February 15	NS	1,736	1,484
March 3	570	1,535	1,436
April 12	608	1,379	1,111
May 6	576	680	489
June 9	592	564	745
July 12	544	606	574
July 27	534	504	—
August 15	NS	487	405
September 1	643	323	371
October 11	512	578	490
November 15	NS	326	370
December 3	685	484	454
1966			
January 14	544	909	947
February 25	358	1,996	636
March 14	470	1,755	2,058
April 1	416	1,079	680
May 3	429	572	786
June 3	614	833	594
July 5	483	354	383
August 1	525	362	456
August 29	566	394	—
September 15	NS	314	328
October 4	467	320	363
November 14	512	971	570
December 2	528	399	489
1967			
January 9	317	1,453	1,292
February 2	557	850	1,012
March 2	435	909	677
March 28	304	544	—
April 15	NS	365	404
May 8	288	385	380
June 6	320	450	452
July 21	422	776	584
August 14	390	351	464
September 20	355	456	521
October 3	352	334	352
November 7	358	609	472
December 14	378	997	846
1968			
January 15	326	994	843
February 20	381	439	484
March 15	394	2,135	858
March 22	422	1,042	—
April 15	NS	481	537
May 15	NS	337	379
June 14	336	348	339
July 11	323	320	318
August 18	336	309	304
September 15	NS	253	258
October 23	305	208	220
November 15	288	223	251
December 12	330	351	364

NS, no sample.

Table 2. Arkansas River at Van Buren, Ark.

Date	Tritium concentration (pCi/liter)	Discharge (m^3/s)	
		Daily	Monthly mean
1961			
October 16	266	2,560	1,325
November	NS		2,128
December 5[a]	176	1,337	1,410
1962			
January	NS		774
February	NS		964
March 15[a]	534	365	827
April	NS		958
May	NS		307
June 27[a]	1,420	513	1,182
July	NS		522
August 31	928	167	327
September	NS		871
October	NS		910
November	NS		465
December	NS		433
1963			
January	NS		315
February	NS		190
March	NS		464
April	1,610		331
May	3,520		277
June	4,830		221
July	5,890		330
August	2,370		196
September	2,320		261
October	2,410		92
November	2,120		65
December	1,300		50
1964			
January	1,240		51
February	1,480		70
March	1,910		145
April	2,140		448
May	2,490		393
June	2,660		615
July	2,670		207
August	2,250		167
September	1,890		333
October	1,780		102
November	NS		778
December	1,220		508
1965			
January	1,410		373
February	1,290		298
March	1,540		414
April	1,290		1,656
May	1,100		600
June	1,180		1,381
July	1,280		780
August	1,240		292
September	1,080		921
October	1,100		448
November	880		159
December	966		151
1966			
January	845		246
February	781		609
March	794		334
April	906		524
May	733		723
June	794		372
July	797		228
August	1,260		318
September	858		294
October	896		179
November	906		145
December	778		118
1967			
January	794		82
February	829		68
March	749		71
April	733		378
May	528		419
June	1,240		588
July	582		1,307
August	698		458
September	582		415
October	621		549
November	579		694
December	474		587
1968			
January	483		526
February	438		1,180
March	490		1,583
April	406		1,735
May	390		1,664
June	464		1,393
July	394		569
August	426		644
September	352		338
October	394		334
November	320		876
December	311		1,329

[a] Sampled at Little Rock, Ark.
NS, no sample.

Samples believed to have tritium concentrations between 250 and 1,000 pCi/liter, are counted directly in a 2-liter gas proportional counter filled to 2 atmospheres of gas pressure with 80 percent hydrogen gas and 20 percent methane. About 2 to 2.5 milliliters of water are converted to hydrogen gas by passing the vapor over uranium metal heated to a temperature of 875° C. The gas proportional system yields a tritium counting efficiency of about 95 percent and background about 2.5 counts per minute.

Samples below 250 pCi/liter are enriched by electrolysis using a technique and electrolysis cells similar to those described by Ostlund and Weiner (*9*). In this procedure, 50, 100, 250, or 500 milliliters of a predistilled water sample are electrolytically reduced to 5 to 10 milliliters of tritium-enriched water containing about 75 to 90 percent of the initial tritium. After a final distillation to remove the neutralized electrolyte, the tritium-enriched sample is counted by one of the above-described systems, depending upon the anticipated final tritium concentration.

Table 3. Colorado River near Cisco, Utah

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily	Monthly mean
1961			
September 21	419	133	150
October 9	490	270	164
1962			
August 14	1,460	93	95
1963			
January	NS		75
February	NS		99
March	3,120		101
April	2,940		116
May	4,480		238
June	5,090		158
July	4,450		53
August	3,580		77
September	3,120		87
October	NS		62
November	2,430		85
December	2,020		64
1964			
January	1,570		61
February	1,440		60
March	1,870		59
April	3,050		102
May	6,140		396
June	7,300		371
July	5,920		127
August	3,740		111
September	3,580		73
October	3,490		75
November	3,140		87
December	2,410		83
1965			
January	1,760		75
February	1,440		72
March	2,270		71
April	3,100		268
May	3,740		586
June	3,970		787
July	3,230		514
August	2,960		206
September	2,500		176
October	2,150		166
1965			
November	2,380		119
December	1,830		109
1966			
January	2,010		92
February	2,120		86
March	1,870		128
April	2,390		209
May	2,310		321
June	2,440		204
July	2,350		85
August	2,460		55
September	2,560		69
October	2,070		80
November	1,890		73
December	2,060		80
1967			
January	NS		67
February	1,550		69
March	1,850		85
April	NS		94
May	1,550		213
June	1,680		340
July	1,570		151
August	NS		81
September	1,530		84
October	1,500		80
November	1,580		100
December	1,470		111
1968			
January	NS		95
February	1,450		95
March	1,350		79
April	1,310		110
May	1,090		307
June	1,390		557
July	1,240		141
August	995		168
September	NS		76
October	1,380		[a] 97
November	1,310		[a] 120
December	1,230		[a] 111

[a] Discharge subject to revision.
NS, no sample

Accuracy

The errors associated with the analytical results listed in the tables average less than ± 10 percent at 1 standard deviation. Some of the earlier analyses may have had a slightly higher average error, but errors in the more recent analyses are known to average less than ± 10 percent.

Discussion of data

Although a more detailed interpretation of the data will be included in a later publication, certain trends that are obvious from the data listed in the tables are discussed here. The large pulse of tritium from precipitation because of thermonuclear testings, as shown by Stewart and Hoffman (*10*), is reflected in all the streams. Also apparent are the seasonal, latitudinal, and continental effects noted in precipitation. The amount of ground water flow relative to runoff appears to affect the response of streams to tritium in precipitation falling in the basin. This might be expected since ground water response to tritium in precipitation is obviously much slower than runoff response. During the early part of the recorded period, most streams contained considerably lower concentrations of tritium than

Table 4. Colorado River at Columbus, Texas

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily	Monthly mean
1964			
December 1	611	6.7	8.8
1965			
January 5	362	6.5	56
February 12	416	274	133
March 8	570	21	18
April 12	352	26	33
May 11	589	148	243
June 9	1,170	246	217
July 9	832	78	69
August 5	835	43	40
September 13	746	47	42
October 21	560	54	27
November 18	544	78	81
December 20	294	255	110
1966			
January 25	339	30	42
February	NS	—	53
March 2	480	72	32
April 5	426	53	72
May 11	608	169	206
June 16	557	72	70
July 26	608	53	56
August 29	518	33	44
September	NS	—	36
October 4	448	23	19
November 7	640	22	22
December 13	352	6.1	6.9
1967			
January 17	208	5.8	5.8
February	NS	—	5.7
March 27	768	30	18
April	NS	—	47
May 1	592	61	72
June 6	570	60	61
July 13	560	45	38
August 15	480	59	57
September 18	336	37	81
October 24	175	22	36
November	NS	—	44
December	NS	—	16
1968			
January 22	125	1,133	239
January 25	194	368	—
February 15	330	181	187
March 12	309	224	170
April 16	271	200	220
May	NS	—	304
June	NS	—	327
July 2	254	191	115
August 1	303	63	59
September	NS	—	83
October	NS	—	[a] 21
November	NS	—	[a] 14
December 4	138	[a] 58	[a] 29
December 18	139	[a] 14	—

[a] Discharge subject to revision.
NS, no sample.

Table 5. Colorado River at Imperial Dam near Yuma, Ariz.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily[a]	Monthly mean[b]
1964			
October	NS	—	183
November 5	1,060	153	133
December	NS	—	120
1965			
January	NS	—	125
February 4	1,150	157	169
March 3	1,320	257	253
April 1	1,440	294	269
May 5	1,370	270	253
June 4	1,330	256	275
July 7	1,540	327	326
August 2	1,470	328	339
September 2	1,500	295	257
October 8	1,500	223	184
November 4	1,540	148	122
December 1	1,410	102	109
1966			
January 5	1,250	80	94
February 1	1,780	99	170
March 2	2,190	219	238
April 6	2,340	324	296
May 3	2,470	256	265
June 2	2,450	287	303
July 5	2,240	337	336
August 8	2,530	347	338
September 1	2,430	304	253
October 3	2,540	201	180
November 3	2,210	154	126
December 2	2,330	133	145
1967			
January 9	2,270	180	139
February 6	2,320	157	188
March 6	2,470	242	273
April 6	2,540	287	266
May 4	2,450	255	253
June 1	2,420	278	283
July 5	2,800	309	310
August 2	2,430	332	310
September 7	2,130	150	214
October 5	2,110	221	190
November 7	1,790	160	128
December 5	1,810	79	80
1968			
January 8	2,140	159	158
February 6	2,080	176	180
March 5	2,050	238	261
April 2	2,210	317	296
May 7	2,120	238	245
June 4	2,010	264	276
July 2	2,010	294	288
August 6	1,930	263	280
September 3	1,860	247	235
October 1	1,810	223	184
November 5	1,740	172	142
December 3	1,650	145	140

[a] At All-American Canal Station 60.
[b] Sum of discharges of All-American Canal, Gila Gravity Main Canal and Colorado River at Imperial Dam.
NS, no sample.

was present in precipitation, whereas later, the concentration of tritium in streams often exceeded that in precipitation. Figure 2 presents an example of this trend.

The Missouri River at Nebraska City, Nebr., shows good agreement between the monthly composite, which consists of equal volumes of daily samples, and the monthly grab sample. This suggests that the response of the river to changes in the rate of tritium input is not abrupt, at least for periods of less than a month. The effect of the nuclear facilities at the Savannah River Plant is obvious when tritium data from the Savannah River are compared to those of other streams. Also

Table 6. Columbia River at Pasco, Wash.

Date	Tritium concentration (pCi/liter)	Discharge (m^3/s)	
		Daily	Monthly mean[a]
1961			
September 15	384	1,844	1,887
October 17	397	1,706	1,805
1962			
July 2	832	6,431	5,490
1963			
April	813		2,913
May	1,330		4,110
June	1,790		7,703
July	2,210		5,731
August	3,230		3,008
September	NS		2,015
October	3,840		1,811
November	3,620		1,679
December	5,540		1,781
1964			
January	4,800		1,698
February	2,980		2,127
March	2,140		1,896
April	1,730		1,855
May	1,540		4,723
June	2,880		11,063
July	3,970		8,404
August	3,870		3,772
September	4,540		2,184
October	4,130		2,585
November	3,780		2,073
December	3,490		2,086
1965			
January	3,310		2,360
February	2,810		3,146
March	2,430		2,788
April	1,920		3,380
May	2,080		6,871
June	2,220		9,048
July	2,830		6,274
August	2,610		3,722
September	2,860		2,274
October	2,640		1,894
November	2,670		2,059
December	2,570		2,170
1966			
January	2,600		1,990
February	2,240		2,355
March	2,050		2,283
April	1,930		2,271
May	1,820		5,276
June	1,820		7,812
July	2,000		6,496
August	2,510		3,170
September	2,090		2,135
October	2,070		1,946
November	1,950		1,916
December	1,800		2,192
1967			
January	1,850		2,237
February	1,890		2,281
March	1,620		2,613
April 24	1,540	3,257	2,620
May 31	1,780	8,242	4,069
June 15	1,790	13,480	12,438
July 28	1,840	5,787	8,211
August 29	1,500	3,648	3,612
September 29	1,440	3,045	2,369
October 31	1,280	1,978	2,141
November 29	1,240	2,759	2,232
December 29	1,370	3,661	2,646
1968			
January 30	1,350	3,087	2,382
February 28	1,360	1,962	2,334
March 25	1,200	3,822	3,326
April	NS		2,889
May 1	1,230	3,048	3,647
June 1	1,170	5,182	7,746
July	NS		6,450
August	NS		3,284
September 3	1,130	2,818	2,646
September 25	1,120	3,062	—
October	NS		2,271
November 5	1,040	2,302	
November 27	1,220	3,418	
December 20	1,270	3,115	

[a] Discharge at Columbia River at Priest Rapids and Yakima River at Kiona, Wash.
NS, no sample.

obvious is the moderating effect of the Great Lakes on the tritium in the St. Lawrence River.

The Colorado River at Cisco, Utah, and most of the other sampled rivers reached their maximum tritium levels in 1963–1964, whereas the Colorado River near Yuma, Ariz., did not reach its highest level until 1966–1967. About a year after the maximum tritium concentration was reached in the Mississippi River, the concentration in the river at Luling, La., began to approximate about half the concentration near Anoka, Minn. The Yukon River carried the highest concentration derived from precipitation, whereas the Kissimee River had the lowest. Although their basins adjoin, the Potomac River had tritium levels significantly lower than the Ohio River.

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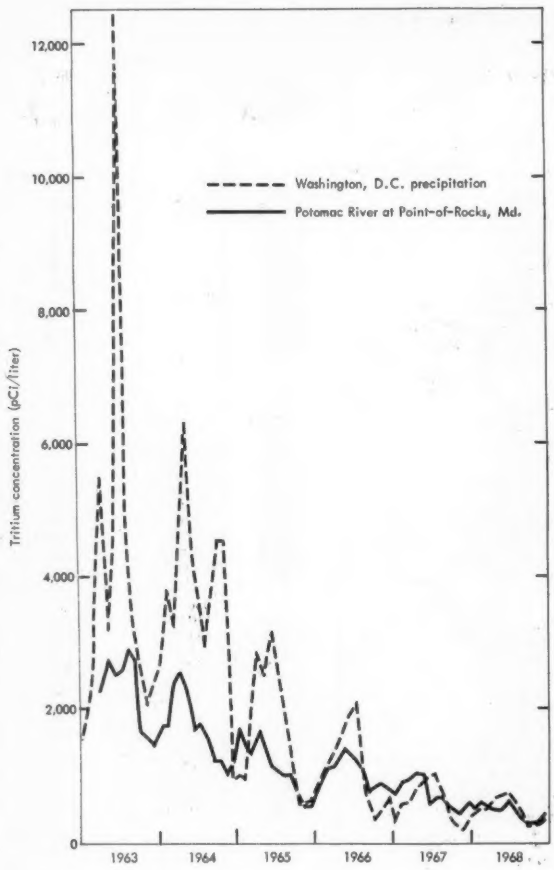

Figure 2. Tritium concentration in Washington, D.C. precipitation and in the Potomac River at Point-of-Rocks, Md.

Table 7. Delaware River at Philadelphia, Pa.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily[a]	Monthly mean[a]
1964			
October 22	2,000	55	61
November 17	1,830	44	54
December 17	1,680	101	111
1965			
January 5	1,410	119	140
February 15	1,340	433	343
March 15	1,310	235	256
April 15	1,250	334	278
May 17	1,570	125	148
May 28	1,450	98	—
June 14	1,580	62	73
July 15	1,480	49	44
August 16	1,560	50	51
September 13	1,380	62	59
October 19	1,180	103	98
November	NS		75
December	NS		143
1966			
January	NS		143
February	NS		256
March 16	1,220	453	502
April 14	1,180	187	220
May 23	1,200	277	301
June 20	1,100	130	176
July	NS		72
August	NS		70
September	NS		77
October	NS		103
November	NS		129
December 7	960	163	199
1967			
January 6	750	196	286
February	NS		246
March 8	840	597	523
April 13	830	411	516
May 4	800	300	426
June 12	830	125	176
July 14	820	221	159
August 3	860	394	286
September	NS		135
October 5	690	114	142
November 9	630	317	252
December	NS		416
1968			
January	NS		193
February	NS		278
March	NS		471
April	NS		334
May	NS		440
June	NS		575
July 10	630	186	201
August 8	610	144	124
September 5	570	114	134
October 1	560	107	124
November 21	540	742	275
December 5	520	515	296

[a] Discharge at Trenton, N.J.
NS, no sample.

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Table 8. Kissimmee River near Okeechobee, Fla.

Date	Tritium concentration (pCi/liter)	Discharge (m^3/s) Daily[a]	Discharge (m^3/s) Monthly mean[a]
1961			
October 17	83.2	15	15
1962			
August 9	570	21	35
September	NS		80
October	NS		38
November	NS		14
December	NS		9
1963			
January	NS		8
February	NS		12
March	NS		24
April	1,050		14
May	1,150		11
June	2,210		15
July	2,050		16
August	NS		13
September	2,240		17
October	1,500		21
November	1,340		16
December	1,250		18
1964			
January	1,120		23
February	1,250		58
March	NS		67
April	NS		44
May	NS		45
June	1,110		37
July	NS		17
August	899		27
September	NS		67
October	NS		72
November	858		24
December	720		11
1965			
January	720		21
February	NS		27
March	659		48
April	570		32
May	656		13
June	618		11
July	688		29
August	541		53

Date	Tritium concentraton (pCi/liter)	Discharge (m^3/s) Daily[a]	Discharge (m^3/s) Monthly mean[b]
1965			
September	435		56
October	291		58
November	336		46
December	NS		19
1966			
January	378		29
February	288		62
March	304		113
April	288		82
May	358		50
June	368		54
July	346		56
August	397		94
September	288		76
October	307		78
November	378		26
December	381		7
1967			
January	378		6
February	NS		7
March	352		5
April	307		3
May	384		11
June	368		14
July	271		15
August	212		48
September	220		69
October	215		47
November	194		7
December	168		7
1968			
January	180		6
February	178		6
March	150		5
April	222		3
May	191		6
June	141		100
July	127		191
August	158		106
September	157		84
October	134		64
November	88.6		22
December	104		10

NS, no sample.

Table 9. Mississippi River near Anoka, Minn.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s) Daily	Discharge (m³/s) Monthly mean
1961			
September 19	315	50	52
October 13	276	82	67
1962			
July 3	947	271	340
1963			
January	NS		103
February	NS		90
March	NS		157
April	1,980		301
May	4,060		287
June	5,890		432
July	4,420		120
August	6,240		155
September	4,480		113
October	3,460		82
November	3,420		81
December	2,620		70
1964			
January	2,430		74
February	2,320		74
March 23	2,370	114	92
April	NS		324
May	NS		450
June	NS		156
July 10	5,280	151	134
August 4	4,640	103	78
September 25	4,160	320	243
October 13	3,420	153	154
November 5	3,330	122	115
December 3	3,170	92	97
1965			
January 12	3,010	93	94
February 8	3,070	86	88
March 29	2,720	88	91
April 23	3,900	1,676	1,175
May 29	3,490	813	778
June 3	2,910	765	777
July 10	3,200	283	250
August 11	3,170	184	162
August 18	3,180	155	—
September	NS		210
October 6	2,360	651	515
November 29	2,510	105	276
December 10	2,540	242	249
1966			
January 12	2,310	204	200
February 16	1,860	411	282
March 25	2,130	1,005	663
April 22	2,440	787	799
May 20	2,480	623	657
June 21	2,450	229	316
July 18	2,360	234	232
August 9	2,280	190	253
August 23	2,550	326	—
September 20	2,410	165	187
October 10	2,050	149	165
November 7	1,850	145	156
December 7	2,030	130	125
1967			
January 4	1,930	125	132
February 8	1,920	138	139
March	NS		191
April 5	1,110	1,150	746
April 26	1,550	538	—
May 17	1,620	331	338
June 12	1,600	257	365
July 18	1,700	171	206
August 10	1,630	102	95
September 20	1,500	87	75
October	NS		
November 20	1,450	90	78
December 14	1,240	71	74
1968			
January 23	1,210	72	67
February 20	1,240	58	68
March 25	1,220	186	134
April 15	990	232	247
May 21	1,170	254	263
June 21	1,100	498	400
July	NS		298
August 1	1,160	193	122
September 4	1,220	83	123
October 1	1,000	227	368
November 12	1,080	286	296
December 12	990	198	163

NS, no sample.

Table 10. Mississippi River at Luling-to-Destrahan Ferry, La.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily[a]	Monthly mean[b]
1962			
September 17	278	8,212	10,050
October 20	224	9,514	11,520
1962			
January 8	358	17,920	21,690
March 6	371	30,700	34,120
July 30	1,450	10,650	10,020
1963			
January	NS		9,577
February	NS		8,614
March	NS		19,420
April	2,910		22,590
May	2,890		9,783
June	4,540		8,696
July	3,740		6,080
August	3,200		5,389
September	3,080		4,344
October	3,230		3,633
November	2,560		3,823
December	2,270		4,616
1964			
January	2,110		5,182
February	2,050		7,192
March	2,110		17,240
April	2,420		23,810
May	2,430		22,820
June	2,980		9,543
July	2,880		8,297
August	2,670		4,814
September	2,470		4,814
October	2,220		5,493
November	2,240		4,842
December	1,500		10,250
1965			
January	1,200		12,090
February	1,220		14,920
March	1,310		17,780
April	1,620		23,640
May	2,080		17,900
June	2,140		11,040
July	2,150		8,750
August	1,740		5,890
1965			
September	1,800		7,192
October	1,140		10,137
November	1,370		6,116
December	1,470		6,230
1966			
January	1,070		11,638
February	877		17,556
March	832		19,057
April	1,140		10,364
May	1,070		20,954
June	1,310		11,100
July	1,400		5,862
August	1,600		5,239
September	1,330		4,842
October	1,290		4,701
November	NS		[a] 7,575
December	1,220		9,316
1967			
January	736		8,155
February	992		7,957
March	800		13,080
April	1,040		14,190
May	864		17,730
June 20	864	12,860	14,410
June 28, 29, 30	835	18,040	—
July	682		13,480
August	816		8,130
September	867		5,663
October	922		6,088
November	NS		8,070
December	NS		13,649
1968			
January	442		17,471
February	506		16,820
March	547		11,638
April	573		22,427
May	531		15,461
June	544		18,717
July	682		8,523
August	755		7,815
September	784		5,125
October	701		5,578
November	NS		6,739
December	NS		11,157

[a] Discharge at Vicksburg, Miss.
[b] Discharge at Tarbert Landing, Miss.
NS, no sample.

Table 11. Missouri River at Nebraska City, Nebr.

Date	Tritium concentration (pCi/liter)	Discharge (m^3/s) Daily	Discharge (m^3/s) Monthly mean
1963			
April	3,620		949
May	4,960		943
June	7,810		1,113
July	4,670		942
August	3,420		950
September	2,940		936
October	3,970		938
November	3,160		899
December	2,700		311
1964			
January	2,020		343
February	1,990		408
March	2,130		545
April	2,940		974
May	3,870		1,067
June	3,870		1,261
July	4,030		968
August	4,540		1,026
September	4,030		964
October	4,480		954
November 16	4,420	1,002	
November	4,220		949
December 21	2,590	425	
December	3,390		390
1965			
January 19	2,700	385	
January	2,750		382
February	2,400		454
March 12	2,850	966	
March	2,720		896
April 21	3,070	1,014	
April	3,010		1,547
May 28	2,860	1,920	
May	3,490		1,285
June	3,190		1,273
July 9	4,000	1,252	
July	3,710		1,140
August 10	5,120	1,022	
August	4,190		1,004
September 13	3,550	1,158	
September	3,200		1,279
October 18	3,580	1,096	
October	3,330		1,261
November 23	3,490	1,124	
November	3,550		1,075
December 8	2,830	733	
December	2,900		727
1966			
January 20	2,970	578	
January	3,050		606
February 9	3,390	1,356	
February	2,150		949
March 3	2,300	923	
March	2,270		902
April 5	2,830	1,133	
April	3,050		1,067
May 17	3,650	1,008	
May	3,360		1,013
June 15	3,780	1,053	
June	3,360		1,105
July 20	3,520	1,008	
July	3,810		1,049
August 4	3,460	1,053	
August	3,520		1,126
September 16	3,300	1,019	
September	3,580		1,012
October 13	3,840	974	
October	3,100		1,028
November 4	3,420	1,036	
November	3,170		1,005
December 15	2,750	510	
December	2,680		488
1967			
January 27	2,180	419	
January	2,530		387
February 16	2,500	481	
February	2,070		433
March 6	2,080	994	
March	1,650		735
April 19	2,970	1,002	
April	2,820		1,033
May 12	2,690	1,158	
May	2,690		1,036
June 26	1,580	2,044	
June	1,570		2,321
July 27	2,400	1,235	
July	2,340		1,192
August 22	2,720	1,090	
August	2,440		1,102
September 20	2,450	1,099	
September	2,630		1,065
October 11	2,150	1,065	
October	2,250		1,083
November 21	2,040	1,042	
November	2,150		1,027
December 13	1,950	651	
December	1,910		594
1968			
January 9	2,250	311	
January	1,830		438
February 14	1,810	719	
February	1,600		694
March 26	1,860	1,036	
March	1,710		820
April 18	2,140	1,065	
April	2,050		1,080
May 16	2,040	1,082	
May	1,860		1,050
June 21	1,960	1,014	
June	1,860		1,117
July 24	1,800	1,201	
July	1,810		1,062
August 28	1,970	1,073	
August	1,880		1,048
September 24	1,780	966	
September	1,800		994
October 16	1,780	1,011	
October	1,730		1,122
November 13	1,620	1,073	
Novembr	1,810		1,086
December 11	1,750	566	
December	1,570		636

Table 12. Neuse River near Vanceboro, N.C.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily[a]	Monthly mean[a]
1961			
October 19	191	13	15
November 1	192	12[b]	17
December	NS		52
1962			
January	NS		144
February	NS		130
March 19	640	232	195
August 2	1,240	41	51
September	NS		35
October	NS		32
November	NS		135
December	NS		75
1963			
January	NS		164
February	NS		159
March	NS		198
April	1,950		68
May	1,760		47
June	2,660		35
July	3,330		24
August	4,190		28
September	2,980		29
October	3,390		17
November	1,920		67
December	1,310		98
1964			
January	992		155
February	1,600		199
March	1,790		188
April	1,270		145
May	1,250		35
June	1,800		23
July	2,270		21
August	1,680		31
September	1,280		113
October	1,000		468
November	1,060		71
December	816		108
1965			
January	864		185
February	813		270
March	752		256
April	826		107
May	1,110		81
June	957		220
July	1,270		322
August	NS		222
September	1,240		40
October	922		24
November	557		20
December	579		20
1966			
January	576		50
February	672		146
March	685		232
April	784		45
May, June	701		
May			106
June			62
July, August	771		
July			18
August			31
September	784		17
October	630		15
November	646		16
December	752		28
1967			
January	768		80
February	502		109
March	515		75
April	432		33
May	448		40
June	512		50
July	544		55
August	554		89
September	422		81
October	NS		27
November	NS		26
December	NS		87
1968			
January	NS		189
February	NS		57
March 19	403	135	93
April 1	419	55	49
May 2	451	29	23
June 1	384	57	47
July 3	515	13	30
August	NS		11
September 5	387	6	6
October 5	358	4	11
November 5	304	8	26
December 5	298	24	29

[a] Discharge at Kinston, N.C.
[b] Instantaneous discharge.
NS, no sample.

Table 13. Ohio River at Markland Dam near Warsaw, Ky.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily[a]	Monthly mean[a]
1961			
September 18	480	456	464
October 19	352	413	663
1962			
August 17	1,470	394	456
1963			
January	NS		2,537
February	NS		2,248
March	NS		12,260
April	3,040		3,483
May	2,770		1,472
June	3,140		1,529
July	3,740		481
August	4,860		481
September	4,800		311
October	3,710		193
November	3,520		430
December	2,210		821
1964			
January	2,570		2,180
February	3,080		2,124
March	3,010		10,900
April	NS		6,456
May	3,090		2,152
June	2,930		910
July	3,810		481
August	NS		453
September	NS		261
October	NS		578
November 17	2,210	255	637
December 15	2,020	5,069	2,860
1965			
January 12	2,380	5,380	4,729
February 16	2,000	7,306	4,729
March 16	1,780	4,078	6,173
April	NS		7,249
May 18	1,960	1,215	1,926
June 2	1,610	844	643
June 18	1,640	527	—
July 16	1,700	614	572
August 17	2,220	255	331
September 24	1,420	348	957
October 22	1,390	1,260	975
November 18	1,200	1,309	1,015
December 19	1,330	1,133	1,072
1966			
January 18	1,120	1,283	2,775
January 21	1,130	909	2,765
February 18	1,220	14,080	6,080
March 18	1,060	2,975	2,972
April 16	1,370	5,935	3,449
May 27	1,190	1,426	5,332
June 24	1,170	694	625
July 22	1,240	378	561
August 18	1,320	1,014	602
September 22	1,170	988	619
October 20	1,190	422	926
November 30	1,110	2,107	1,642
December 21	1,170	2,353	3,993
1967			
January 20	1,220	1,133	1,801
February 20	1,030	2,701	2,945
March 23	816	10,730	9,911
April 24	864	4,389	4,332
May 15	688	10,020	7,419
May 17	688	11,520	—
June 16	832	872	1,138
July 25	896	668	883
August 17	778	408	793
September 18	720	303	541
October 16	787	722	1,220
November 14	749	1,121	1,614
December 19	589	2,818	3,710
1968			
January 16	618	1,594	2,549
February 21	630	1,051	3,908
March 18	560	7,617	5,239
April 22	762	1,623	3,936
May 8	598	1,294	5,663
June 10	669	2,362	3,964
July 23	723	917	838
August 12	646	3,313	1,337
September 17	630	759	490
October 21	746	1,031	617
November 13	602	1,087	1,566
December 11	650	2,308	2,602

[a] Discharge at Louisville, Ky. minus Kentucky River at Lockport, Ky.
NS, no sample.

Table 14. Potomac River at Point-of-Rocks, Md.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s) Daily	Discharge (m³/s) Monthly mean
1961			
November 3	272	56	72
December 10	320	57	189
1962			
June 5	1,020	161	165
1963			
January	NS		246
February	NS		126
March	NS		1,091
April	2,240		209
May	2,720		126
June	2,500		166
July	2,560		55
August	2,900		37
September	2,750		35
October	1,630		28
November	1,540		72
December	1,440		107
1964			
January	1,730		437
February	1,730		281
March	2,400		738
April	2,530		445
May	2,300		361
June	1,660		78
July	1,750		61
August	1,590		39
September	1,190		30
October	1,220		67
November	990		63
December	1,280		151
1965			
January	1,720		383
February	1,360		457
March	1,330		677
April 1–14	1,610	[a] 423	—
April	1,660		419
May	1,390		202
June	1,090		66
July	1,040		42
August	1,020		35
September	1,000		34
October	640		43
November	541		33
December	534		35
1966			
January	NS		54
February 14–28	1,040	[a] 559	329
March	1,120		298
April	1,140		302
May 1–10	1,390	[a] 673	341
June	NS		68
July 8–31	1,280	[a] 28	30
August	1,060		26
September	774		115
October	848		165
November	896		105
December	797		195
1967			
January	723		221
February	912		256
March 1–24	989	[a] 1,000	889
March 25–31	1,090	[a] 511	—
April	1,040		229
May	1,020		436
June	566		126
July	672		124
August	675		149
September 1–24	563	[a] 74	75
October	NS		153
November	451		112
December	605		441
1968			
January 1–23	522	[a] 243	320
February	605		413
March	560		614
April	515		212
May	493		332
June 1–25	630	[a] 288	261
July	NS		66
August	362		51
September 1–14	306		49
October	320		[b] 43
November	336		[b] 137
December	426		[b] 98

[a] Mean discharge for period.
[b] Discharge subject to revision.
NS, no sample.

Table 15. Sacramento River at Sacramento, Calif.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily	Monthly mean
1961			
September 18[a]	144	294	274
October 24[a]	96	197	201
December 12	240	340	444
1962			
March 21	477	807	1,070
August 14	384	343	327
1963			
January	NS		546
February	NS		1,588
March	NS		692
April[a]	1,790		1,745
May[a]	1,500		1,211
June[a]	1,120		498
July[a]	1,600		344
August[a]	1,290		325
September[a]	608		459
October[a]	813		401
November	NS		641
December	NS		594
1964			
January	NS		700
February[a]	704		591
March[a]	672		407
April[a]	864		354
May[a]	813		395
June[a]	928		314
July	NS		329
August[a]	806		344
September[a]	928		375
October 22	1,060	246	275
October[a]	896		—
November[a]	1,060		393
December 1	976	447	1,035
December[a]	864		—
1965			
January 5	960	2,410	2,033
January[a]	864		—
February 3	717	1,750	1,302
1965			
February[a]	675		—
March 2	928	835	653
March[a]	870		—
April 1	915	648	1,194
May 5	851	960	852
June 4	979	586	454
July 9	1,010	328	344
August 5	880	371	409
September 23	800	473	439
October 19	736	405	395
November 5	723	405	571
December 21	544	614	640
1966			
January 20	464	866	978
February 11	502	926	765
March 9	474	479	671
April 14	656	810	615
May	NS		402
June 2	630	263	271
July 11	646	314	328
July 21	525	362	—
August 25	576	317	348
September 27	589	281	310
October	NS		259
November 6	704	326	527
December	422		1,314
1967			
January 18	458	456	1,022
February 28	406	799	1,465
March 29	422	1,229	1,184
April 11	336	1,458	1,426
April 25	358	1,608	—
May 29	368	1,739	1,470
June 16	400	1,229	1,218
July 28	384	447	552
August 25	416	430	426
September 29	400	481	526
1968			
July 22	320	345	357
December 12	217	640	650

[a] Sampled at Red Bluff, Calif.
NS, no sample.

Table 16. Klamath River near Klamath, Calif.

Date	Tritium concentration (pCi/liter)	Discharge (m^3/s)	
		Daily	Monthly mean
1964			
October 29	842	97	83
November	NS		244
December 1	1,020	1,671	2,485
1965			
January	NS		1,732
February 25	704	643	893
March 24	896	453	525
April 30	1,000	685	611
May	NS		433
June 9	886	317	273
July 15	717	103	108
August 26	678	116	83
September	NS		95
October 6[a]	768	116	122
November 21	531	362	272
December	NS		287
1966			
January 8	845	1,835	949
February 3	586	481	467
February 25	496	459	—
March 30[a]	595	1,025	823
April 26	602	640	820
May	NS		485
June	NS		212
July	NS		102
August	NS		73
September 26	496	77	75
October	NS		88
November 2	458	90	283
November 28	442	253	—
December	NS		822
1967			
January 3	586	234	841
February 8	576	878	805
March 6	512	379	660
April	NS		562
May 22	515	1,141	832
June	NS		451
July 25	560	95	133
August 30	314	74	78
September	NS		76
October	NS		111
November 9	368	123	185
December 14	265	234	308
1968			
January 15	255	3,256	662
February	NS		1,237
March 11	349	561	690
April 1	309	549	389
May 1	316	306	251
June 4	319	187	142
July 16	330	81	82
August 21	264	79	73
September	NS		71
October 2	269	63	101
November	NS		344
December	NS		720

[a] Sampled at Del Norte, Calif.
NS, no sample.

Table 17. Savannah River near Clyo, Ga.

Date	Tritium concentration (pCi/liter)	Discharge (m^3/s)	
		Daily	Monthly mean
1963			
May 1	1,500	234	468
1964			
October 25	7,870		599
November	NS		474
December 1	6,300	391	510
December 29	9,020	634	—
1965			
January			698
February 1	11,170	597	491
March 2	5,280	555	631
April 1	11,270	943	787
April 3	10,270	1,048	—
May 28	7,620	269	398
June	NS		379
July 1	4,260	648	374
August 2	17,500	379	357
September 1	32,320	252	274
October 1	6,370	242	251
December 1	9,950	243	246
1966			
January 4	27,740	248	336
February 2	10,340	348	404
March 1	14,270	663	953
March 31	9,760	671	—
April 26[a]	260	270	330
May 2	10,620	297	379
June 1	4,190	510	390
July 1	10,240	270	257
August 3	15,940	225	248
September	6,340	229	226
October	NS		217
November	NS		217
December	NS		228
1967			
January	NS		355
February	NS		313
March	NS		368
April	NS		238
May 25	5,630	294	253
June 7	9,470	265	453
June 15	4,260	462	—
July	NS		344
August 16	16,540	271	271
September 25	5,500	216	345
October 3	5,090	230	217
November 20	4,770	218	251
December 12	3,520	419	443
1968			
January 18	6,180	654	676
February 15	6,720	262	362
March 18	9,380	297	263
April 15	14,620	264	258
May 20	17,150	262	253
June 17	7,710	419	309
July 12	6,530	261	238
August 15	6,110	234	229
September 17	7,710	212	214
October 15	13,150	212	216
November 13	7,580	237	232
December 16	7,710	231	230

[a] Sampled at Aiken, S.C.
NS, no sample.

Table 18. St. Lawrence River at Alexandria Bay, N.Y.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily[a]	Monthly mean[a]
1964			
October 29	704	5,748	5,805
November 27	640	5,522	5,663
December 23	528	5,607	5,465
1965			
January 25	592	5,465	5,182
February 23	608	5,380	5,154
March 28	576	4,502	5,097
April 25	624	4,814	5,210
May 26	880	4,955	4,984
June 26	704	5,522	5,352
July 25	800	5,748	5,692
August 26	928	5,918	5,833
September 29	835	5,522	5,748
October 25	778	5,947	5,748
November 26	701	5,947	5,947
December 22	771	6,796	6,428
1966			
January 23	672	5,748	6,286
February 27	723	5,805	6,286
March 26	675	6,116	6,626
April 26	694	6,513	6,626
May 25	752	5,805	6,003
June 6	848	5,890	6,003
June 23	787	6,145	—
July 24	707	6,230	6,201
August 22	694	6,230	6,230
September 21	685	6,258	6,258
October 22	694	6,116	6,116
November 21	634	5,890	6,003
December 22	691	6,541	6,145
1967			
January 23	701	6,428	6,201
February 23	864	6,654	6,456
March 26	640	5,239	6,088
April 24	672	6,286	6,003
May 27	688	6,286	6,201
June 26	826	6,031	6,173
July 26	784	6,343	6,400
August 25	579	6,683	6,598
September 25	605	6,456	6,570
October 25	547	7,419	7,051
November 26	576	8,070	7,844
December 22	659	7,872	7,957

[a] Discharge at Ogdensburg, N.Y.

Table 19. Susquehanna River at Harrisburg, Pa.

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily	Monthly mean
1960			
November 9	160	303	276
1961			
September 18	336	145	183
October 18	384	97	98
November 7	208	118	228
1962			
March 20	912	1,481	2,193
April 15	1,090	3,568	3,044
May	NS		642
June 20	1,120	229	208
June 28	928	155	208

Table 19. Susquehanna River at Harrisburg, Pa. —Continued

Date	Tritium concentration (pCi/liter)	Discharge (m³/s)	
		Daily	Monthly mean
1964			
October 19	1,210	82	71
November 20	1,180	57	73
December 16	1,340	309	210
1965			
January	NS		473
February 16	2,050	2,010	1,156
March 15	2,050	937	1,038
April 15	2,080	1,603	1,512
May 17	2,110	654	729
May 26	1,890	388	729
June 16	1,810	186	243
July 14	1,790	105	94
August 18	1,760	97	109
September 15	1,660	97	114
October 15	1,560	309	269
November 16	1,610	265	303
December 15	1,580	357	424
1966			
January	NS		487
February 18	1,280	3,228	1,382
March 15	1,300	2,599	2,079
April 28	1,450	1,889	938
May 16	1,370	2,209	1,522
June 16	1,430	487	431
July 11	1,440	121	113
August 31	1,240	70	93
September 15	1,050	178	124
October 14	1,140	129	147
November 15	1,260	447	321
December 15	1,100	1,220	797
1967			
January 26	915	433	531
February 23	928	685	785
March 24	992	1,424	2,210
April 26	1,070	1,116	1,707
May 17	998	2,860	1,800
May 24	960	1,359	1,800
June 19	922	538	486
July 17	1,180	428	376
August 29	992	626	504
September 28	730	178	272
October 31	797	1,167	749
November 29	794	1,328	1,207
December 20	854	1,243	1,228
1968			
January	NS		470
February	NS		1,038
March 11	784	362	1,563
April 30	746	569	895
May 27	806	1,608	1,303
June	NS		1,420
July 3	691	1,099	472
July 24	698	223	472
August 23	611	138	152
September 26	531	185	330
October 25	586	195	172
November	NS		1,193
December 19	672	566	888

NS, no sample.

Table 20. Yukon River at Ruby, Alaska

Date	Tritium concentration (pCi/liter)	Discharge (m^3/s)	
		Daily	Monthly mean
1961			
September 17	740	6,400	7,180
October 13	610	[a] 1,700	[a] 5,120
December 12	510	[a] 1,610	[a] 1,610
1962			
January 31	2,500	[a] 1,420	[a] 1,420
May 31	1,570	21,290	[a] 7,470
July 16	1,530	3,340	13,870
July 31	1,490	12,800	—
September 21	990	8,440	10,480
1963			
June	6,020		13,040
July	6,750		13,490
August	7,710		12,810
1964			
June	7,840		24,500
July	8,580		15,530
August	8,130		10,660
September	4,580		7,750
October	4,100		[a] 4,240
1965			
August 19	4,580	11,350	9,700
August 28	3,200	8,440	
1966			
July 8	2,680		
August 1–16	2,140		
1968			
June 3–17	1,200		
June 18–July 17	1,440		
July 18–August 16	1,310		
August 18	1,380		
August 18–September 1	1,180		
September 2–30	1,360		
October 1–18	1,300		

[a] Ice affected.

Natural Environmental Radioactivity in South Florida Sands and Soils February-June 1968

Douglas H. Keefer and *Maxwell Dauer*[1]

An investigation of the naturally occurring gamma-emitting radionuclides present in selected sands and soils of south Florida was conducted. Although the primary interest was in the natural environmental radioactivity from uranium-238, radium-226, thorium-232, and potassium-40, the concentrations of five fission products were also determined to minimize the error in computing the concentrations of the four naturally occurring radionuclides. The determination of these nine radionuclides in 45 environmental samples was performed by the linear least-squares method of analysis utilizing a computer.

A comprehensive radiological surveillance study of natural environmental radioactivity was the first to be conducted in south Florida with the exception of the Turkey Point Nuclear Reactor Programs of the Public Health Service and the State of Florida. The Turkey Point studies consisted of soil analyses for potassium-40, radium-226, and thorium-232, on a limited scale. There had been no attempt, however, to assay soil and sand samples beyond this area.

The sampling criterion was based upon differences in the soil associations of south Florida (*1*). The wide variety of sand and soil types with variations from the west to east coast and into the Keys provided ample environmental sampling opportunities.

The environmental radiological data on the naturally occurring radionuclides in south Florida, obtained through this study, will provide those agencies interested in establishing an environmental baseline with an indication of radionuclide concentrations. This information is necessary because the operation of nuclear power reactors in south Florida will require the establishment of preoperational baseline determinations by the responsible State and federal health agencies.

[1] Mr. Keefer was in the Training Manpower Development Program, Bureau of Radiological Health, U.S. Department of Health, Education, and Welfare; and Dr. Dauer is a professor of Radiological Physics in the Department of Radiology, University of Miami Graduate School, Miami, Fla.

In addition to the radiological surveillance data obtained, geological formation data are also indicated by the presence of four natural sources of radioactivity (uranium-238, radium-226, thorium-232, and potassium-40). For example, the Miami oolite formation of the Homestead area extends beneath the surface and reappears in the western Keys. Other geological formations reported in the literature were confirmed by this radiological analysis.

Review of Florida environmental radioactivity

Williams et al. (*2*) and Roessler (*3*) state that the natural environmental radioactivity occurring in Florida moves in the environment because of phosphate mining, phosphate fertilizer production, and subsequent use of byproducts. Other typical sources of environmental radioactivity, such as uranium mining, concentrating or milling; nuclear fuel fabrication or reprocessing; and commerical radioactive waste disposal activities; do not take place in Florida.

Recent studies conducted by the Florida State Board of Health and the U.S. Public Health Service were the principal sources of data on radioactivity in the south Florida environment. These surveys were primarily concerned with fallout and the potential contamination of the environment with reactor byproducts in the vicinity of the Turkey Point Nuclear Reactor site (*4*). However, the naturally occurring radionuclides were also investigated because of their

analytical interference with man-made radionuclides. Potassium–40, thorium–232, and radium–226 concentrations have been reported in soil samples collected by the U.S. Public Health Service's Southeastern Radiological Health Laboratory since 1966 (*5*).

Aerial radiometric surveys of the Atlantic Coast beaches from Florida to North Carolina were conducted by the U.S. Geological Survey and the U.S. Atomic Energy Commission during May to November 1953 (*6*). These surveys did not locate any areas of significantly high gamma radiation in southern Florida.

Mahdavi (*7*) states that during weathering, thorium and uranium are separated to the extent that tetravalent uranium is oxidized to the hexavalent state, leached, and transported in solution as the soluble uranyl ion or its soluble complexes. By comparison, thorium, having only a tetravalent state, remains in primary or secondary resistate[2] minerals (*8*), which concentrate in residual soils (*9*) or are transported as clastic particles. Unoxidized tetravalent uranium in resistates, for example, zircon ($ZrSiO_4$), remains with thorium.

The assumption of secular radioactive equilibrium between thorium and uranium has not been experimentally proved because of sampling and experimental difficulties, but earlier work (*10*) and general agreement with independent and spectrochemical potassium values (*11*) support the assumption. If the thorium and uranium are largely contained in quartz and other resistates (e.g., zircon and monazite), it is unlikely that they have been separated from their radioactive daughters to an important extent. Conversely, any nonresistant or fine grained mineral in which the thorium and uranium are likely to be out of secular radioactive equilibrium with their daughter products is also likely to be quickly removed by the action of waves on the beaches. Carbonate shells formed in the last hundred thousand years are known to be out of equilibrium by not having all the radionuclide daughters that could be supported by the uranium present. To the extent that shells and shell debris are present on the beach, there will be more uranium present than that indicated by analysis of the gamma radiation from the beach (*7*).

Osmond (*12*) states that the coral formations in southern Florida, including Key Largo limestone and Miami oolite, consist of aragonitic carbonates. These have a much higher uranium content than those of normal limestones. The important determining factor is probably the "room" in the crystal lattice of argonite rather than some function of organic activity involved in its formation.

Mahdavi (*7*) further states that, in general, there seemed to be consistent changes from shore to dune across all beach profiles. These changes in concentrations of thorium and uranium and the thorium to uranium ratio must be largely due to the relative proportions of clay and radioactive resistate mineral, particularly when more than 1 to 2 p.p.m. thorium and 0.3 to 0.6 p.p.m. uranium are found. These latter concentrations are most frequently found in pure beach sands and may be considered as the average thorium and uranium content of quartz and feldspar.

Mahdavi's (*7*) study gives most of the available information on thorium, uranium, and potassium concentrations in beach sands with four conclusions:

1. Thorium above 1–2 p.p.m. and uranium above 0.3–0.6 p.p.m. in beach sands are contained in dense, resistate minerals, such as monazite, zircon, and xenotime.

2. Most beaches have a thorium to uranium ratio of 2.5–3, and only the Galveston Island, Tex., and the Cape Cod, Mass., beaches had a thorium to uranium ratio near the 3.8 crustal average.

3. The concentrations of thorium, uranium, and potassium and the thorium to uranium ratio can be related to provenance[3] and beach processes in several cases and can probably be used as natural radioactive tracers and process indicators in many geological situations.

4. The most frequent concentrations found in beach sands are 1–2 p.p.m. thorium and 0.3–0.6 p.p.m. uranium, but the mean concentrations are unknown, being greatly affected by the irregular occurrence of dense resistate minerals, such as monazite and zircon.

[2] Resistate, any of the class of sediments, as sand or sandstone consisting chiefly of minerals resistant to weathering.

[3] Provenance, place or source of origin.

Sampling and analytical procedures

Samples of sand and soil were obtained by selecting an appropriate area of approximately 3,000 cm². The surface of this area was cleared of debris and sampled to a depth of 5 to 10 cm. The individual samples were homogeneously mixed when dry, and large components (e.g., pieces of limestone) were crushed. The sample was then placed in a tared polyethylene Marinelli beaker, tamped to a 2-liter volume and weighed. The range of sample weights was 1.9 kg to 3.6 kg, representing light organic soil to insoluble Miami oolite limestone composition, respectively.

A Nuclear Data 180 counting system was used to perform the gamma pulse-height analysis. The detector system consisted of a 3-by 3-inch aluminum clad NaI(Tl) crystal detector surrounded by a 2-inch-thick cylinder of lead with an inside diameter of 8 inches. This shield was lined with 1 mil of copper and 1/2 mil of aluminum foil to reduce the production of the characteristic lead x ray. The high-voltage power supply was stabilized with a voltage regulator, and line voltage fluctuations were observed to be minimal.

Standardization

The pulse-height analyzer was calibrated to give a channel coefficient of 10 keV per channel using a combination disc source of cesium–137 and cobalt–60. This calibration was repeated for each sample or standard counted.

The counting system was standardized for the natural radionuclides of interest: potassium–40, radium–226 (in equilibrium), uranium–238, and thorium–232. In addition, standard samples of the following fission products were prepared: cerium-praseodymium–144, ruthenium-rhodium–106, cesium-barium–137, zirconium-niobium–95, and manganese–54. All standards were prepared in a 2-liter volume of dry ACS grade sodium chloride weighing 2.855 kilograms to approximate the mean density of the sand and soil samples, which had a range of 1.9 kg to 3.6 kg per 2-liter volume. Backgrounds were subtracted from the standards and net counts used to determine sample activity.

An extended counting period of 200 minutes (four times that normally used by environmental radiological laboratories utilizing 4- by 4-inch crystal detectors) was used. This increased counting time helped overcome the poorer sensitivity of the 3- by 3-inch crystal detector, permitting a more reliable comparison of low-level environmental data.

Data computations

Normally, to correct each sample spectrum for the contribution from natural background radiation, the background spectrum is first subtracted from the sample spectrum. This study used a different approach. The method used consisted of selecting a composite natural background spectrum representative of the counting system being used. These background data were added as a standard spectrum to the computer program. A ten component linear least-squares fitting program was used to determine the magnitude of each of the nine radionuclides of interest and the ratio of the individual background spectrum to the composite background spectrum. The ratio of the background spectra, called the background variation ratio, should be close to 1.000. This has the effect of evaluating the reliability of the least-squares gamma analysis computation as a function of the sample's background deviation from unity (table 1). The inclusion of 95-percent confidence limits (C.L.) for this background variation also provides a range in which the expected variation should occur. Background variations outside the 95-percent confidence limits occurred in less than 10 percent of the results with most variations occurring in less than 5 percent. The presence of radium–226 daughter products not in equilibrium accounts for this variation of sample background.

The solution of complex gamma-ray spectra containing ten components (including natural background) further complicated by gain shifts of the sample and each of the standard components, necessitated the use of a linear least-squares fitting program developed by R. L. Health et al. (*13*) for an IBM 7040. This program included a gain shift routine.

The final product of this program is an intensity factor of the standard and its standard deviation (SD) that is present in the sample. This value, when multiplied by the total activity of the standard and divided by the weight of the sample

Table 1. Environmental analysis of southern Florida sands and soils, February–June 1968[a]

Sampling location	Sample number and type	Sample weight (kg)	Background variation ratio	Radionuclide concentration (pCi/kg, dry weight)							
				^{238}U	^{144}Ce–Pr	^{106}Ru–Rh	^{137}Cs–Ba	^{95}Zr–Nb	^{40}K	^{226}Ra	^{232}Th
Marco Island (SL)[c]	1 Sand	3.30	1.001 ± 0.020	110 ± 30	480 ± 160	ND	ND	17 ± 12	360 ± 290	1,060 ± 280	140 ± 20
Marco Island (BB)[b]	2 Sand	3.22	.970 ± .020	120 ± 30	590 ± 170	ND	41 ± 26	31 ± 13	ND	1,060 ± 310	160 ± 20
Everglades City	3 Soil	3.00	.973 ± .010	120 ± 40	640 ± 190	240 ± 230	48 ± 28	20 ± 14	510 ± 340	1,100 ± 330	200 ± 20
Chokoloskee	4 Sand	3.40	1.071 ± .035	240 ± 70	2,070 ± 490	ND	180 ± 50	44 ± 24	830 ± 530	6,220 ± 990	460 ± 60
Ochopee	5 Soil	3.00	1.046 ± .034	290 ± 70	1,000 ± 420	ND	ND	37 ± 7	1,030 ± 620	5,630 ± 1,110	590 ± 60
Midway	6 Soil	2.40	1.097 ± .042	400 ± 120	2,030 ± 690	ND	850 ± 130	ND	1,610 ± 950	9,150 ± 1,820	730 ± 90
Sweetwater	7 Soil	3.20	1.034 ± .034	210 ± 70	1,730 ± 390	ND	330 ± 70	120 ± 30	840 ± 550	6,300 ± 1,060	400 ± 50
Hialeah	8 Soil	2.60	1.036 ± .024	260 ± 60	1,360 ± 360	ND	1,350 ± 80	28 ± 22	880 ± 530	4,190 ± 970	330 ± 50
South Miami	9 Soil	2.70	1.100 ± .028	160 ± 60	970 ± 370	ND	230 ± 70	ND	800 ± 590	5,570 ± 940	340 ± 40
Pembroke Park	10 Soil	3.25	.995 ± .020	140 ± 30	840 ± 180	ND	470 ± 30	75 ± 13	330 ± 300	980 ± 310	110 ± 20
	11 Soil	3.35	.983 ± .012	110 ± 20	390 ± 100	ND	18 ± 15	15 ± 8	330 ± 200	510 ± 180	80 ± 10
Golden Beach (SL)	12 Sand	3.40	.997 ± .029	96 ± 46	440 ± 240	ND	ND	ND	ND	1,140 ± 430	150 ± 30
Golden Beach (BB)	13 Sand	3.50	0.996 ± .021	59 ± 33	720 ± 180	350 ± 240	71 ± 26	34 ± 13	350 ± 310	1,210 ± 310	150 ± 20
Miami Beach (SL)	14 Sand	2.85	1.003 ± .013	100 ± 20	460 ± 120	220 ± 180	ND	ND	430 ± 240	760 ± 220	82 ± 14
Miami Beach (BB)	15 Sand	3.15	1.016 ± .016	90 ± 26	370 ± 130	ND	47 ± 21	18 ± 11	260 ± 260	740 ± 240	80 ± 16
Key Biscayne (SL)	16 Sand	2.80	1.028 ± .009	110 ± 30	530 ± 180	ND	ND	21 ± 14	650 ± 340	940 ± 310	85 ± 20
Key Biscayne (BB)	17 Sand	3.45	.970 ± .017	90 ± 27	690 ± 140	300 ± 200	65 ± 22	44 ± 11	390 ± 260	890 ± 250	110 ± 20
Upper Key Largo	18 Soil (Oolite)	2.98	1.044 ± .032	330 ± 80	1,850 ± 450	ND	110 ± 50	110 ± 20	990 ± 520	4,810 ± 950	310 ± 50
Homestead Bayfront Park	19 Soil	2.41	1.063 ± .014	280 ± 70	1,250 ± 370	ND	310 ± 50	40 ± 24	770 ± 570	5,440 ± 970	410 ± 50
Homestead	20 Soil	2.10	1.016 ± .035	230 ± 90	560 ± 500	ND	850 ± 120	94 ± 36	930 ± 830	3,720 ± 1,360	200 ± 60
	21 Soil (Oolite)	2.81	1.072 ± .031	230 ± 60	1,190 ± 370	ND	130 ± 70	31 ± 24	920 ± 560	5,640 ± 960	330 ± 50
	22 Soil	2.16	1.045 ± .026	300 ± 80	1,230 ± 440	ND	1,030 ± 80	54 ± 29	740 ± 660	5,230 ± 1,210	390 ± 60
	23 Soil	2.10	1.071 ± .026	370 ± 80	1,330 ± 430	ND	950 ± 80	66 ± 28	830 ± 660	5,920 ± 1,190	360 ± 60
	24 Soil	2.80	1.006 ± .028	220 ± 30	1,000 ± 370	830 ± 480	500 ± 70	69 ± 24	ND	5,600 ± 1,030	332 ± 50
	25 Soil	2.40	1.128 ± .031	350 ± 80	910 ± 470	ND	1,090 ± 90	71 ± 29	920 ± 330	7,550 ± 1,330	430 ± 70
	26 Soil	1.93	1.048 ± .020	400 ± 80	ND	ND	500 ± 50	59 ± 23	750 ± 540	4,120 ± 930	240 ± 50
Turkey Point	27 Sand	3.60	1.332 ± .039	220 ± 60	1,330 ± 360	ND	ND	76 ± 24	760 ± 540	4,550 ± 910	320 ± 50
Homestead	28 Soil (Silt)	2.10	1.103 ± .029	360 ± 80	900 ± 450	ND	120 ± 70	35 ± 30	1,020 ± 700	7,230 ± 1,280	430 ± 60
Turkey Point	29 Soil (Silt)	.80	.962 ± .030	390 ± 210	ND	520 ± 260	ND	130 ± 80	3,480 ± 1,970	5,590 ± 1,970	750 ± 130
Cross Key	30 Soil	3.20	1.096 ± .034	120 ± 60	1,790 ± 430	ND	130 ± 50	100 ± 20	760 ± 520	4,700 ± 930	270 ± 50
Flamingo (SL)	31 Sand	2.30	1.075 ± .023	84 ± 47	ND	ND	52 ± 38	28 ± 20	820 ± 480	1,050 ± 440	140 ± 30
	32 Sand	1.90	1.092 ± .023	150 ± 60	ND	ND	160 ± 50	38 ± 26	ND	1,610 ± 600	320 ± 40
	33 Sand (Clay)	2.70	1.078 ± .041	250 ± 90	960 ± 530	ND	130 ± 70	ND	2,430 ± 780	7,750 ± 1,530	690 ± 80
	34 Sand	2.10	1.082 ± .030	120 ± 70	ND	ND	72 ± 57	36 ± 29	910 ± 710	1,570 ± 670	240 ± 40
Hens and Chickens Reef	35 Sand	2.40	.995 ± .014	150 ± 30	500 ± 160	310 ± 240	ND	35 ± 13	580 ± 320	810 ± 290	63 ± 19
Chev Shore Reef	36 Sand	2.40	1.025 ± .014	120 ± 30	340 ± 160	270 ± 240	ND	26 ± 13	530 ± 320	1,060 ± 290	65 ± 18
Atlantic Ocean bottom	37 Sand	3.00	.980 ± .019	200 ± 40	880 ± 240	ND	40 ± 27	ND	ND	1,070 ± 330	130 ± 30
Islamorada (BB)	38 Sand	2.50	1.030 ± .018	150 ± 40	730 ± 210	330 ± 300	150 ± 30	94 ± 17	ND	1,300 ± 380	94 ± 24
Long Key (SL)	39 Sand	1.90	.997 ± .017	210 ± 50	ND	ND	ND	38 ± 19	ND	860 ± 420	90 ± 28
Long Key (BB)	40 Sand	2.50	.999 ± .015	94 ± 34	580 ± 180	410 ± 260	47 ± 27	67 ± 15	400 ± 340	1,070 ± 320	81 ± 21
Marathon (SL)	41 Sand	2.60	.988 ± .018	130 ± 30	480 ± 170	330 ± 260	ND	30 ± 14	ND	1,030 ± 310	82 ± 20
Marathon (BB)	42 Sand	2.50	.971 ± .017	120 ± 40	470 ± 190	ND	ND	30 ± 15	560 ± 370	1,290 ± 340	89 ± 22
Bahia Honda Park	43 Sand	3.10	.997 ± .020	110 ± 40	620 ± 190	ND	34 ± 28	31 ± 15	ND	1,580 ± 340	120 ± 20
Key West (SL)	44 Sand	2.75	1.025 ± .023	210 ± 60	780 ± 290	ND	ND	31 ± 20	610 ± 460	4,970 ± 820	260 ± 40
Key West (BB)	45 Sand	3.00	1.038 ± .025	200 ± 50	1,010 ± 300	ND	57 ± 41	43 ± 20	620 ± 460	5,120 ± 770	270 ± 40

[a] The error expressed is the relative 1.96-sigma counting error.
[b] BB, beach back.
[c] SL, sea level, front beach.
ND, nondetectable.

in kilograms, expresses the activity of the respective radionuclide per kilogram of sample. The 95-percent confidence limit is obtained by following the above steps with the SD and then multiplying the result by 1.96.

Analysis of beach sands

The profile of a beach in a line perpendicular to the water's edge consists of a front beach at sea level, the berm, the back beach, and finally the dune. In this study, beach-sand samples were collected from the front and back beach areas (whenever the beach was wide enough) to present a profile. This sampling procedure was followed to permit observation of the systematic changes in the thorium to uranium ratio from shore to dune reported by Mahdavi (7). The two sampling areas (the front and back beaches) were reported to be the low and high ratios, respectively. The same phenomenon was observed in the beach sands of south Florida.

The thorium-232 and uranium-238 values reported for south Florida were within the range of the most frequent concentrations reported for the north Gulf and Atlantic Coast beaches (7). However, as observed in table 2, the thorium

Table 2. Natural environmental radioactivity in the sands and soils of southern Florida, February–June 1968

Sample number[a]	Concentration (dry weight)				Th/U ratio
	Potassium (mg/g)	Radium-226 (pg/g)	Uranium-238 (p.p.m.)	Thorium-232 (p.p.m.)	
Sand:					
1	0.42 ±0.34[b]	1.0 ±0.3[b]	0.3 ±0.1[b]	1.2 ±0.2[b]	3.7
2	ND	1.0 ± .3	.4 ± .1	1.4 ± .2	4.0
4	.97 ± .62	6.1 ±1.0	.7 ± .2	4.2 ± .5	5.8
12	ND	1.1 ± .4	.3 ± .1	1.4 ± .3	4.8
13	.42 ± .36	1.2 ± .3	.2 ± .1	1.4 ± .2	7.7
14	.51 ± .28	.7 ± .2	.3 ± .1	.7 ± .1	2.4
15	ND	.7 ± .2	.3 ± .1	.7 ± .1	2.7
16	.76 ± .40	.9 ± .3	.3 ± .1	.8 ± .2	2.2
17	.46 ± .30	.9 ± .2	.3 ± .1	1.0 ± .2	3.7
27	.90 ± .63	4.5 ± .9	.7 ± .2	2.9 ± .5	4.4
31	.96 ± .56	1.0 ± .4	.3 ± .1	1.3 ± .3	5.0
32	ND	1.6 ± .6	.5 ± .2	2.9 ± .4	6.2
33	2.86 ± .91	7.6 ±1.5	.7 ± .3	6.2 ± .7	8.3
34	1.08 ± .84	1.5 ± .6	.4 ± .2	2.1 ± .4	5.9
35	.68 ± .38	.8 ± .3	.5 ± .1	.6 ± .2	1.2
36	.62 ± .38	1.0 ± .3	.4 ± .1	.6 ± .2	1.6
37	ND	1.1 ± .3	.6 ± .1	1.2 ± .2	2.0
38	ND	1.3 ± .4	.4 ± .1	.8 ± .2	1.9
39	ND	.8 ± .4	.7 ± .2	.8 ± .3	1.1
40	.48 ± .40	1.1 ± .3	.3 ± .1	.7 ± .2	2.6
41	ND	1.0 ± .3	.5 ± .1	.7 ± .2	1.6
42	.66 ± .43	1.2 ± .3	.4 ± .1	.8 ± .2	2.3
43	ND	1.5 ± .3	.3 ± .1	1.1 ± .2	3.4
44	.72 ± .54	4.9 ± .8	.6 ± .1	2.3 ± .3	3.6
45	.73 ± .54	5.0 ± .8	.6 ± .2	2.4 ± .3	4.0
Soil:					
3	.60 ± .40	1.1 ± .3	.4 ± .1	1.8 ± .2	5.0
5	1.21 ± .72	5.5 ±1.1	.9 ± .2	5.3 ± .5	6.2
6	1.90 ±1.12	9.0 ±1.8	1.2 ± .4	6.5 ± .8	5.5
7	.99 ± .65	6.2 ±1.0	.6 ± .2	3.6 ± .5	5.6
8	1.05 ± .63	4.1 ± .9	.8 ± .2	3.0 ± .4	3.8
9	.94 ± .70	5.5 ± .9	.5 ± .2	3.1 ± .4	6.4
10	.39 ± .35	.9 ± .3	.4 ± .1	1.0 ± .2	2.3
11	.39 ± .23	.5 ± .2	.3 ± .1	.8 ± .1	2.2
18	1.16 ± .61	4.7 ± .9	1.0 ± .2	2.8 ± .5	2.9
19	.90 ± .67	5.3 ± .9	.8 ± .2	3.7 ± .5	4.5
20	1.10 ± .97	3.6 ±1.3	.7 ± .3	1.8 ± .5	2.6
21	1.08 ± .66	5.5 ± .9	.7 ± .2	3.0 ± .4	4.3
22	.87 ± .78	5.1 ±1.2	.9 ± .2	3.5 ± .5	4.0
23	.98 ± .78	5.8 ±1.2	1.1 ± .2	3.2 ± .5	2.9
24	ND	5.5 ±1.0	.7 ± .1	3.0 ± .5	4.6
25	1.09 ± .39	7.4 ±1.3	1.1 ± .2	3.8 ± .6	4.0
26	.88 ± .64	4.0 ± .9	1.2 ± .2	2.1 ± .5	1.8
28	1.20 ± .82	7.1 ±1.3	1.1 ± .2	3.9 ± .6	3.6
29	4.10 ±2.31	5.4 ±1.9	1.2 ± .6	6.7 ±1.2	5.8
30	.89 ± .61	4.6 ± .9	.4 ± .2	2.4 ± .4	6.6

[a] Sampling locations are given in table 1.
[b] The error expressed is the relative 1.96-sigma-counting error.
ND, nondetectable.

to uranium ratios are above the mean range of 2.5–3.0 reported by Mahdavi, with the exception of the Key Largo to Marathon sampling locations (numbers 35 to 42). The mean thorium to uranium ratio for all beach sands collected in south Florida was 3.7, within a range of 1.1 to 8.3. The mean concentration for thorium-232 was 1.6 ± 0.3 p.p.m., in a range of 0.6 to 6.2 p.p.m. The mean concentration for uranium–238 was 0.7 ± 0.1 p.p.m., with a range of 0.2 to 0.7 p.p.m.

The beach sands of south Florida have a mean thorium to uranium ratio of 3.7. This ratio is considerably higher than those reported for the north Florida Gulf Coast and south Atlantic Coast beaches, which are 2.1 and 2.8, respectively. The south Florida thorium to uranium ratio approximates the earth's crustal average of 3.8, as do the beaches of Galveston, Tex., and Cape Cod, Mass. It appears that the geological formation of Miami oolite limestone, so prevalent in south Florida, is responsible for the higher ratio.

Seven pairs of the beach sand samples confirmed that the back beach thorium to uranium ratio is higher than the front beach ratio in south Florida sands. This was also observed by Mahdavi for the Gulf Coast and Atlantic Coast beaches. This change in concentration is due to the relative proportions of clay and radioactive resistate minerals, which vary from the front of the beach to the back of the beach, as influenced by the action of sea.

Table 2 shows that the highest thorium to uranium ratios generally appear in samples also containing the highest radium–226 concentrations. The possibility of radium–226 interfering with uranium and thorium results is minimized, however, by examining the analysis of samples having similarly high thorium to uranium ratios with low radium–226 activity. The mean radium–226 content of the south Florida sands was 2.0 ± 0.5 pg/g, with a range of 0.7 to 7.6. The sand samples, consisting primarily of Miami oolite limestone had the highest average concentration of radium–226, approximately 5 pg/g. Those sand samples consisting of Key Largo limestone had the lowest average radium–226 concentration, approximately 2 pg/g.

The fission products detected in the south Florida sands had maximum values (per kilogram of dry sample weight) as follows: cerium-praseodymium–144, 2,070 pCi; ruthenium-rhodium–106, 410 pCi; cesium-barium–137, 180 pCi; and zirconium-niobium–95, 110 pCi.

Relatively low concentrations of natural potassium are found in south Florida sands and soils. The results were reported as nondetectable within this confidence interval in several cases. This phenomenon has also been observed by the Public Health Service and Florida State Board of Health in their environmental surveys of south Florida soil (*5, 14*). The mean concentration of natural potassium (determined by potassium–40 assay) was 0.53 ± 0.32 mg/g of sand, with a range from nondetectable to 2.9 mg/g. The mean potassium concentration in soils was 1.1 ± 0.7 mg/g, with a range of 0.39 to 4.1 mg/g. The potassium content of 0.046 percent reported by Mahdavi for the north Florida Gulf Coast beach is comparable to the south Florida beach value of 0.053 percent.

Analysis of soil

The 20 soil samples assayed provide an insight into the naturally occurring environmental radioactivity that exists throughout south Florida. The mean thorium to uranium ratio in soil samples was 4.2, in a range of 1.8 to 6.6 (table 2). The mean thorium–232 concentration was 3.3 ± 0.5 p.p.m., in a range of 0.8 to 6.7 p.p.m. The mean uranium–238 concentration was 0.8 ± 0.2 p.p.m. in a range of 0.3 to 1.2 p.p.m.

The environmental analysis of natural radioactivity in south Florida soils indicates a mean thorium to uranium ratio of 4.2. This ratio is the result of a two-fold increase in the mean thorium–232 concentration, accompanied by only a small increase in the mean uranium–238 content over the reported concentrations for sands in south Florida. The radium–226 concentration in soil samples was approximately 2.5 times the radium–226 found in sand samples. Since radium–226 is a daughter product of the uranium–238 series, the difference between soil and sand concentrations must be the result of nonsecular equilibrium between daughter products washed away by the action of waves on the beach. The parent radionuclide, uranium–238, is present in equal quantities (approximately 0.75 p.p.m.) in both sand and soil.

The geological formation of southern Florida consists of two major limestone structures. Mi-

ami oolite, comprising the east coast ridge on the mainland, appears in the Homestead area (sample number 21), descends to form the floor of the southern Everglades and is again observed at Flamingo (sample numbers 31 through 34). The oolite formation then emerges west of Big Pine Key and influences the natural environmental radioactivity of Key West (sample numbers 44 and 45). The Key Largo limestone formation (having low thorium-232 and radium-226 concentrations) forms the Keys and the offshore ocean floor from Key Largo to Marathon (sample numbers 35 through 42) and is observed radiometrically at eight sampling locations in this study.

The radioanalysis of samples for natural environmental radioactivity collected from the Turkey Point Nuclear Reactor area (sample numbers 19 through 29) will assist the Public Health Service and the Florida State Board of Health in preoperational surveys. The range of uranium-238 in these samples was from 0.66 to 1.2 p.p.m.; the range of thorium-232 was from 1.8 to 3.8 p.p.m., with thorium to uranium ratios from 1.8 to 5.5.

Many soil samples contained pieces of Miami oolite, since the widely distributed Perrine-Ochopee soil association consists of marly materials overlying limestone. This oolite contribution is significant in determining the radiological environmental profile of the area. The PHS analysis of soil samples from this area ascertained similar levels of natural environmental activity.

The fission products detected in south Florida soils had value ranges, (per kilogram of dry sample weight) as follows: cerium-praseodymium-144, nondetectable to 2,030 pCi; ruthenium -rhodium-106, nondetectable to 830 pCi. Ruthenium-rhodium-106 values were less than the detectable levels (below the 95-percent confidence limits) for most soil samples assayed. Values of cesium-barium-137 ranged from nondetectable to 1,350 pCi; and zirconium-niobium-95, from nondetectable to 120 pCi. Manganese-54 was detectable (above the 95-percent confidence limit) in only two of the 45 samples. This expected frequency supports the observation that manganese-54 no longer contributes significantly to environmental radioactivity in south Florida.

Conclusion

Four conclusions can be drawn from this environmental investigation of natural radioactivity in south Florida:

1. The thorium to uranium ratio of Florida's southern peninsula is significantly higher than the reported ratio of the north Florida Gulf coast and south Atlantic coast beaches. This higher ratio is caused primarily by the presence of Miami oolite limestone formation indigenous to this area. High radium-226 concentrations, approximately 5 pg/g, can also be expected when a sample contains a high percentage of Miami oolite.

2. If a sample contains Key Largo limestone, it is anticipated that the thorium to uranium ratio will be approximately 2.0, because thorium-232 concentrations are about one-third of the range found in Miami oolite. Radium-226 activity in a sample containing a significant amount of the Key Largo limestone will be approximately 2 pg/g.

3. The uranium-238 concentration in sands and soils of southern Florida is approximately 0.75 p.p.m. This level of natural environmental radioactivity is expected because of the higher uranium content of specific limestone formations native to south Florida.

4. The potassium concentrations of south Florida beach sands and sandy-type soils compare closely with the reported values from the north Florida Gulf coast area.

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Data

SECTION I. MILK AND FOOD

Milk Surveillance, May 1970

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation and/or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Bureau of Radiological Health and the Bureau of Foods, Pesticides and Product Safety, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations; 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Public Health Service)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that occur in, or are formed as a result of, nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements, calcium and potassium, which are found in milk, have been used as a means for assessing the biological behavior of

Figure 1. Milk sampling networks in the Western Hemisphere

metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variation, expressed in terms of 2-standard deviations for these concentrations are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for the period, May 1963–March 1966 (*3*) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Bureau of Radiological Health conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested public health radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted during July–September 1969, with 31 laboratories participating in an experiment on milk samples containing known concentrations of strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. Of the 18 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 14 participated in the experiment.

The iodine-131 and cesium-137 results show much improvement over previous tests. Barium-140 results also look good, which is encouraging, since this is the first time barium-140 was analyzed for this type of experiment. However, strontium-89 and strontium-90 analyses still need improvement (*5*). Keeping these possible differences in mind, integration of the data from the various networks can be undertaken without introducing a serious error due to disagreement among the independently obtained data.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methodologies, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports*.

A recent article (*6*) summarizes the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and earlier data articles for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. The frequency of collection and analysis varies not only among the networks but also at different stations within some the of networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short time periods, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data presentation also reflects whether raw or pasteurized milk was collected. A recent analysis (*7*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milkshed or

sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant. Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard deviation counting errors or 2-standard deviation total analytical errors from replicate analyses experiments (*3*). The practical reporting level reflects additional analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks give practical reporting levels greater than those above. In these cases the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurement equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical errors or precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (3). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter
Iodine-131, Cesium-137, Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥100 pCi/liter

For iodine-131, cesium-137, and barium-140 there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions is presented below. The function of the Council is to provide guidance to Federal agencies in the formulation of radiation standards.

Radiation Protection Guides (*8, 9*)

The Radiation Protection Guide (RPG) has been defined by the Federal Radiation Council (FRC) as the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable. An RPG provides radiation protection guidance for the control and regulation of normal peacetime uses of nuclear technology in which control is exercised primarily at the source through the design and use of nuclear material. It represents a balance between the possible risk to the general public that might result due to exposures from routine uses of ionizing radiation and the benefits from the activities causing the exposure.

Table 1 presents a summary of guidelines and related information on environmental radiation levels as set forth by the FRC for the conditions under which RPG's are applicable. A more detailed discussion of these values was presented earlier (*3*).

In the absence of specific dietary data one can use milk as the indicator food item for routine surveillance. Assuming a 1-liter per day intake of milk, one can utilize the graded approach of daily intake on the basis of radionuclide content

Table 1. Radiation Protection Guides—FRC recommendations and related information pertaining to environmental levels during normal peacetime operation

Nuclide	Critical organ	RPG for individual in the general population (rad/a)	Guidance for suitable samples of exposed population group[a]				
			RPG (rad/a)	Corresponding continuous daily intake (pCi/day)	Range I[b] (pCi/day)	Range II[b] (pCi/day)	Range III[b] (pCi/day)
Strontium-89	Bone	[c] 1.5	0.5	[d] 2,000	0-200	200-2,000	2,000-20,000
	Bone marrow	[c] .5	.17				
Strontium-90	Bone	[c] 1.5	.5	[d] 200	0-20	20-200	200-2,000
	Bone marrow	[c] .5	.17				
Iodine-131	Thyroid	1.5	.5	100	0-10	10-100	100-1,000
Cesium-137[e]	Whole body	.5	.17	3,600	0-360	360-3,600	3,600-36,000

[a] Suitable samples which represent the limiting conditions for this guidance are: strontium-89, strontium-90—general population; iodine-131—children 1 year of age; cesium-137—infants.

[b] Based on an average intake of 1 liter of milk per day.

[c] A dose of 1.5 rad/a to the bone is estimated to result in a dose of 0.5 rad/a to the bone marrow.

[d] For strontium-89 and strontium-90, the Council's study indicated that there is currently no operational requirement for an intake value as high as one corresponding to the RPG. Therefore, these intake values correspond to doses to the critical organ not greater than one-third the respective RPG.

[e] The guides expressed here were not given in the FRC reports, but were calculated using appropriate FRC recommendations.

in milk samples collected to represent general population consumption. Under these assumptions, the radionuclide concentrations in pCi/liter of milk can replace the daily radionuclide intake in pCi/day in the three graded ranges.

Protective Action Guides (*10, 11*)

The Protective Action Guide (PAG) has been defined by the Council as the projected absorbed dose to individuals in the general population that warrants protective action following a contaminating event. A PAG provides general guidance for the protection of the population against exposure by ingestion of contaminated foods resulting from the accidental release or the unforeseen dispersal of radioactive materials in the environment. A PAG is also based on the assumption that such an occurrence is an unlikely event, and circumstances that might involve the probability of repetitive occurrences during a 1 or 2-year period in a particular area would require special consideration. Protective actions are appropriate when the health benefits associated with the reduction in exposure to be achieved are sufficient to offset the undesirable features of the protective actions.

Table 2 presents a summary of guidelines as set forth by the FRC for the conditions under which PAG's are applicable. A more detailed discussion of these values was presented earlier (*3*). Also given in table 2 are milk concentration for each of the radionuclides considered, in the absence of others, which if attained after an

Table 2. Protective Action Guides—FRC recommendations and related information pertaining to environmental levels during an acute contaminating event

Radionuclide	Critical organ	PAG for individuals in general population (rads)	Category (pasture-cow-milk)	
			Guidance for suitable sample, children 1 year of age	
			PAG (rads)	Maximum concentration in milk for single nuclide that would result in PAG (pCi/liter)
Strontium-89	Bone marrow			[c] 1,110,000
Strontium-90	Bone marrow	10 in first yr; total dose not to exceed 15[a,b]	3 in first yr; total dose not to exceed 5[a,b]	[c] 51,000
Cesium-137	Whole body			[c] 720,000
Iodine-131	Thyroid	30	10	[d] 70,000

[a] The sum of the projected doses of these three radionuclides to the bone marrow should be compared to the numerical value of the respective guide.

[b] Total dose from strontium-89 and cesium-137 is the same as dose in first year; total dose from strontium-90 is 5 times strontium-90 dose in first year for children approximately 1 year of age.

[c] These values represent concentrations that would result in doses to the bone marrow or whole body equal to the PAG, if only the single radionuclide were present.

[d] This concentration would result in the PAG dose based on intake before and after the date of maximum concentration observed in milk from an acute contaminating event. A maximum of 84,000 pCi/liter would result in a PAG dose if that portion of intake prior to the maximum concentration in milk is not considered. Children, 1 year of age, are assumed to be the critical segment of the population.

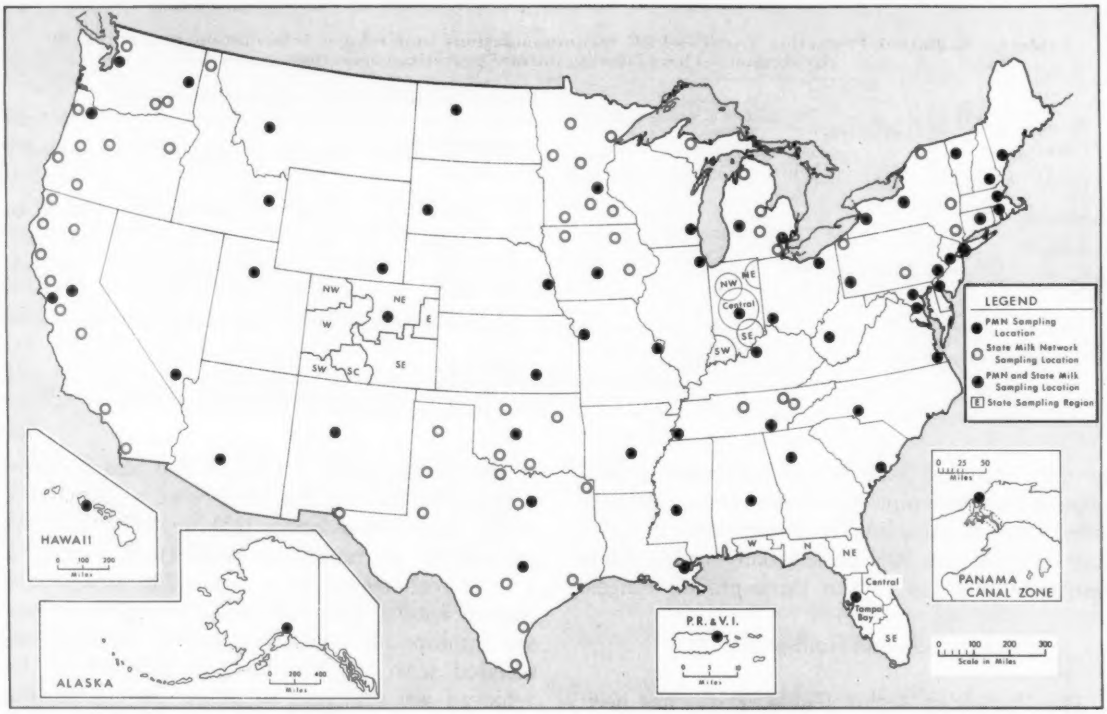

Figure 2. State and PMN milk sampling locations in the United States

acute incident, would result in doses equivalent to the appropriate PAG. These concentrations are based on a projection of the maximum concentration from an idealized model for any acute deposition and the pasture-cow-milk-man pathway, as well as an estimate of the intake prior to reaching the maximum concentration. Therefore, these maximum concentrations are intended for use in estimating future intake on the basis of a few early samples rather than in retrospective manner.

Data reporting format

Table 3 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports.* (The relationship between the PMN stations and State stations is shown in figure 2). The first column under each of the radionuclides reported gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12-monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 3, surveillance results are given for strontium-90, iodine-131, and cesium-137 for May 1970 and the 12-month period, June 1969

Table 3. Concentration of radionuclides in milk for May 1970 and 12-month period June 1969 through May 1970

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES:								
Ala:	Montgomery[c]	P	4	6	0 (4)	0	12 (4)	10
Alaska:	Palmer[c]	P	4	5	0 (3)	0	8 (3)	4
Ariz:	Phoenix[c]	P	3	1	0 (4)	0	0 (4)	0
Ark:	Little Rock[c]	P	17	14	0 (4)	0	13 (4)	17
Calif:	Sacramento[c]	P	0	1	0 (5)	0	0 (5)	0
	San Francisco[c]	P	2	1	0 (4)	0	0 (4)	0
	Del Norte	P	25	20	0	0	17	19
	Fresno	P	2	2	0	0	0	7
	Humboldt	P	6	4	0	0	0	6
	Los Angeles	P	2	2	0	0	0	4
	Mendocino	P	5	3	0	0	0	3
	Sacramento	P	2	2	0	0	0	3
	San Diego	P	2	2	0	0	0	2
	Santa Clara	P	2	2	0	0	0	3
	Shasta	P	6	3	0	0	0	4
	Sonoma	P	4	3	0	0	0	4
Colo:	Denver[c]	P	5	5	0 (4)	0	0 (4)	2
	West	R	(d)		(e)	1	(e)	5
	Northeast	R	(d)		(e) (7)	(e)	(e) (7)	(e)
	East	R	(d)		NS	(e)	NS	(e)
	Southeast	R	(d)		NS	(e)	NS	(e)
	South central	R	(d)		NS	NS	NS	NS
	Southwest	R	(d)		NS	(e)	NS	4
	Northwest	R	(d)		(e)	(e)	(e)	(e)
Conn:	Hartford[c]	P	8	8	0 (5)	0	14 (5)	10
	Central	P	7	7	0 (5)	0	10 (5)	11
Del:	Wilmington[c]	P	8	8	0 (4)	0	5 (4)	5
D.C:	Washington[c]	P	9	7	0 (5)	0	9 (5)	6
Fla:	Tampa[c]	P	6	6	0 (2)	0	53 (2)	53
	West	R	NA	11	NA	0	NA	21
	North	R	NA	12	NA	0	NA	25
	Northeast	R	NA	7	NA	0	NA	50
	Central	R	NA	7	NA	0	NA	44
	Tampa Bay area	R	NA	7	NA	0	NA	53
	Southeast	R	NA	8	NA	0	NA	79
Ga:	Atlanta[c]	P	14	10	0 (4)	0	19 (4)	18
Hawaii:	Honolulu[c]	P	0	2	0 (4)	0	0 (4)	0
Idaho:	Idaho Falls[c]	P	4	5	0 (4)	0	6 (4)	3
Ill:	Chicago[c]	P	11	7	0 (4)	0	10 (4)	8
Ind:	Indianapolis[c]	P	8	8	0 (4)	0	0 (4)	4
	Northeast	P	9	9	0	1	15	13
	Southeast	P	14	10	0	0	15	12
	Central	P	10	9	0	0	10	10
	Southwest	P	16	11	0	0	10	12
	Northwest	P	9	10	0	0	10	17
Iowa:	Des Moines[c]	P	5	6	0 (4)	0	0 (4)	2
	Iowa City	P	NS		NS		NS	
	Des Moines	P	NS		NS		NS	
	Spencer	P	NS		NS		NS	
	Fredericksburg	P	NS		NS		NS	
Kans:	Wichita[c]	P	9	8	0 (4)	0	0 (4)	0
Ky:	Louisville[c]	P	11	8	0 (4)	0	10 (4)	4
La:	New Orleans[c]	P	15	15	0 (5)	0	23 (5)	18
Maine:	Portland[c]	P	11	11	0 (4)	0	22 (4)	22
Md:	Baltimore[c]	P	9	8	0 (4)	0	3 (4)	6
Mass:	Boston[c]	P	13	11	0 (4)	0	22 (4)	20
Mich:	Detroit[c]	P	9	8	0 (4)	0	10 (4)	8
	Grand Rapids[c]	P	10	9	0 (4)	0	9 (4)	10
	Bay City	P	NA	7	(e) (2)	(e)	10 (2)	9
	Charlevoix	P	18	12	(e) (4)	(e)	13 (4)	18
	Detroit	P	14	7	(e) (4)	(e)	6 (4)	6
	Grand Rapids	P	10	9	(e) (4)	(e)	7 (4)	11
	Lansing	P	NA	8	(e) (2)	(e)	12 (2)	15
	Marquette	P	21	13	(e) (2)	1	24 (2)	24
	Monroe	P	7	6	(e) (2)	(e)	0 (2)	2
	South Haven	P	NA	NA	(e) (4)	(e)	0 (4)	3
Minn:	Minneapolis[c]	P	9	10	0 (4)	0	9 (4)	7
	Bemidji	P	5	16	0	0	20	25
	Mankato	P	4	7	0	0	0	0
	Rochester	P	5	8	0	0	12	0
	Duluth	P	14	17	0	0	21	24
	Worthington	P	0	6	0	0	0	0
	Minneapolis	P	6	11	0	0	12	12
	Fergus Falls	P	4	8	0	0	0	11
	Little Falls	P	15	9	0	0	20	12
Miss:	Jackson[c]	P	15	12	0 (3)	0	13 (3)	12
Mo:	Kansas City[c]	P	8	8	0 (4)	0	8 (4)	2
	St. Louis[c]	P	8	8	0 (4)	0	7 (4)	2
Mont:	Helena[c]	P	5	5	0 (4)	0	3 (4)	5
Nebr:	Omaha[c]	P	6	6	0 (5)	0	0 (5)	1
Nev:	Las Vegas[c]	P	3	1	0 (4)	0	0 (4)	0

See footnotes at end of table.

Table 3. Concentrations of radionuclides in milk for May 1970 and 12-month period June 1969 through May 1970—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES—Continued								
N.H:	Manchester[c]	P	5	8	0 (4)	0	15(4)	16
N.J:	Trenton[c]	P	8	8	0 (4)	0	7 (4)	5
N. Mex:	Albuquerque[c]	P	2	3	0 (4)	0	0 (4)	0
N.Y:	Buffalo[c]	P	7	7	0 (5)	0	6 (5)	7
	New York City[c]	P	9	10	0 (4)	0	10 (4)	12
	Syracuse[c]	P	5	7	0 (4)	0	14 (4)	9
	Albany	P	9	4	0 (4)	0	([e]) (4)	([e])
	Buffalo	P	([e])	([e])	0 (3)	0	([e]) (3)	([e])
	Massena	P	7	6	0 (2)	0	26 (2)	([e])
	Newburg	P	12	6	0 (4)	0	([e]) (4)	([e])
	New York City	P	11	7	0 (5)	0	([e]) (5)	([e])
	Syracuse	P	4	3	0 (2)	0	([e]) (2)	([e])
N.C:	Charlotte[c]	P	12	12	0 (4)	0	9 (4)	12
N. Dak:	Minot[c]	P	9	10	0 (4)	0	17 (4)	15
Ohio:	Cincinnati[c]	P	10	8	0 (4)	0	8 (4)	3
	Cleveland[c]	P	9	9	0 (5)	0	9 (5)	5
Oklahoma:	Oklahoma City[c]	P	7	7	0 (3)	0	8 (3)	8
	Oklahoma City	P	NS		NS		NS	
	Enid	P	NS		NS		NS	
	Tulsa	P	NS		NS		NS	
	Lawton	P	NS		NS		NS	
	Ardmore	P	NS		NS		NS	
Oreg:	Portland[c]	P	6	6	0 (5)	0	7 (5)	6
	Baker	P	4	3	0	0	0	0
	Coos Bay	P	10	5	0	0	21	12
	Eugene	P	2	2	0	0	0	6
	Medford	P	3	2	0	0	0	8
	Portland composite	P	4	4	0	0	10 (4)	6
	Portland local	P	7	5	0	0	8 (4)	9
	Redmond	R	4	2	0	0	0	3
	Tillamook	R	7	6	0	0	21	13
Pa:	Philadelphia[c]	P	9	9	0 (5)	0	10 (5)	5
	Pittsburgh[c]	P	11	11	0 (4)	0	12 (4)	8
	Dauphin	P	7	7	0	3	0	10
	Erie	P	8	10	0	6	12	24
	Philadelphia	P	6	8	0	4	0	10
	Pittsburgh	P	6	11	0	3	12	19
R.I:	Providence[c]	P	8	9	0 (4)	0	17 (4)	15
S.C:	Charleston[c]	P	10	10	0 (4)	0	21 (4)	22
S. Dak:	Rapid City[c]	P	6	8	0 (4)	0	0 (4)	3
Tenn:	Chattanooga[c]	P	10	9	0 (4)	0	7 (4)	12
	Memphis[c]	P	11	9	0 (4)	0	9 (4)	4
	Chattanooga	P	9	12	3 (4)	0	20 (4)	14
	Clinton	P	16	16	0	0	17	11
	Knoxville	P	11	10	0 (2)	0	13 (2)	6
	Nashville	P	9	8	0 (2)	0	7 (2)	7
	Fayetteville	P	15	12	0 (2)	0	10 (2)	14
Tex:	Austin[c]	P	3	2	0 (4)	0	0 (4)	3
	Dallas[c]	P	11	6	0 (4)	0	9 (4)	7
	Amarillo	R	NS	4	NS	0	NS	0
	Corpus Christi	R	3	4	0	0	0	2
	El Paso	R	4	2	0	0	0	0
	Fort Worth	R	NS	4	NS	0	NS	2
	Harlingen	R	NS	3	NS	0	NS	0
	Houston	R	NS	7	NS	0	NS	10
	Lubbock	R	5	4	0	0	0	0
	Midland	R	NS	2	NS	0	NS	0
	San Antonio	R	NS	4	NS	0	NS	0
	Texarkana	R	NS	10	NS	0	NS	0
	Tyler	R	13	9	0	0	0	5
	Uvalde	R	3	3	0	0	0	0
	Wichita Falls	R	13	9	0	0	0	0
Utah:	Salt Lake City[c]	P	4	4	0 (4)	0	0 (4)	2
Vt:	Burlington[c]	P	6	8	0 (4)	0	10 (4)	12
Va:	Norfolk[c]	P	9	10	0 (5)	0	10 (5)	8
Wash:	Seattle[c]	P	5	6	0 (4)	0	0 (4)	7
	Spokane[c]	P	6	6	0 (2)	0	0 (2)	3
	Benton County	R	0	0	0	0	0	7
	Franklin County	R	NS	2	NS	0	NS	3
	Sandpoint, Idaho	R	11	11	0	0	25	26
	Skagit County	R	5	6	0	0	17	13
W. Va:	Charleston[c]	P	9	9	0 (4)	0	6 (4)	5
Wisc:	Milwaukee[c]	P	6	7	0 (5)	0	10 (5)	10
Wyo:	Laramie[c]	P	4	5	0 (4)	0	0 (4)	2
CANADA								
Alberta:	Calgary	P	([g])		([d])		23	18
	Edmonton	P	([g])		([d])		16	16
British Columbia:	Vancouver	P	([g])		([d])		27	29
Manitoba:	Winnipeg	P	([g])		([d])		29	24

See footnotes at end of table.

Table 3. Concentrations of radionuclides in milk for May 1970 and 12-month period June 1969 through May 1970—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
CANADA—Continued								
New Brunswick:	Frederickton	P	([g])		([d])		20	19
Newfoundland:	St. Johns	P	([g])		([d])		35	35
Nova Scotia:	Halifax	P	([g])		([d])		21	21
Ontario:	Ft. William	P	([g])		([d])		20	29
	Ottawa	P	([g])		([d])		17	13
	Sault Ste. Marie	P	([g])		([d])		31	29
	Toronto	P	([g])		([d])		12	11
	Windsor	P	([g])		([d])		9	10
Quebec:	Montreal	P	([g])		([d])		16	17
	Quebec	P	([g])		([d])		21	25
Saskatchewan:	Regina	P	([g])		([d])		22	13
	Saskatoon	P	([g])		([d])		15	11
CENTRAL AND SOUTH AMERICA:								
Colombia:	Bogota	P	2	2	0	0	10	4
Chile:	Santiago	P	0	0	0	0	0	2
Ecuador:	Guayaquil	P	0	4	0	5	0	0
Jamaica:	Mandeville	P	4	4	0	0	60	86
Venezuela:	Caracas	P	2	2	0	0	0	0
Canal Zone:	Cristobal[c]	P	2	0	0 (4)	0	5 (4)	9
Puerto Rico:	San Juan[c]	P	5	3	0 (3)	0	7 (3)	7
PMN Network average[f]			8	7	0	0	8	8

[a] P, pasteurized milk. R, raw milk.
[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.
[c] PHS Pasteurized Milk Network station. All other sampling locations are part of the State or National network.
[d] Radionuclide analysis not routinely performed.
[e] The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:

Iodine-131: Colorado—25 pCi/liter	Cesium-137: Colorado—25 pCi/liter	Strontium-90: New York—3 pCi/liter
Michigan—14 pCi/liter	New York—20 pCi/liter	
Oregon—15 pCi/liter	Oregon—15 pCi/liter	

[f] This entry gives the average radionuclide concentrations for the PHS Pasteurized Milk Network stations denoted by footnote [c].
[g] Monthly samples were collected and composited for quarterly analysis of strontium-90.
NA, no analysis.
NS, no sample collected.

to May 1970. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89 and barium-140 data have been omitted from table 3 since levels at the great majority of the stations for May 1970 were below the respective practical reporting levels. Table 4 gives monthly averages for those stations at which strontium-89 was detected.

Iodine-131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower values reflected by the radiation protection guidance provided by the Federal Radiation Council (table 1), levels in milk for this radionuclide are of particular public health interest. In general, the practical reporting level for iodine-131 is numerically equal to the upper value of Range I (10 pCi/liter) of the FRC radiation protection guide.

Table 4. Strontium-89 in milk, May 1970

Sampling location		Radionuclide concentration (pCi/liter)
Alaska:	Palmer (PMN)	6
Calif:	Del Norte (State)	19
	Humboldt (State)	8
	Shasta (State)	7
Ky:	Louisville (PMN)	11
La:	New Orleans (PMN)	6
Mo:	St. Louis (PMN)	7
N.Y:	Massena (State)	7(2)
Ore:	Portland (PMN)	7
Tex:	Dallas (PMN)	7
W. Va:	Charleston (PMN)	9

Strontium-90 monthly averages ranged from 0 to 25 pCi/liter in the United States for the month of May 1970, and the highest 12-month average was 20 pCi/liter (Del Norte, Calif.) representing 10.0 percent of the Federal Radiation Council radiation protection guide (table

1). Cesium-137 monthly averages ranged from 0 to 53 pCi/liter in the United States for May 1970, and the highest 12-month average was 79 pCi/liter (Southeast Fla.), representing 2.2 percent of the value presented in this report using the recommendations given in the Federal Radiation Council reports. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (*12*) and Jamaica. Iodine-131 results for individual samples were all below the practical reporting level.

The Canadian Department of National Health and Welfare changed their analysis pattern in May 1970. Monthly samples will be collected and composited for quarterly analysis of strontium-90.

Acknowledgement

Appreciation is expressed to the personnel of the following health agencies who provide data for their milk surveillance networks:

Bureau of Radiological Health
Division of Environmental Sanitation
California State Department of Health

Radiological Health Section
Division of Air, Occupational and Radiation Hygiene
Colorado State Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiological Health Service
Division of Occupational Health
Michigan Department of Health

Radiation Protection Division
Canadian Department of National Health and Welfare

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Health
Division of Environmental Health Services
New York State Department of Health

Division of Occupational and Radiological Health
Environmental Health Services
Oklahoma State Department of Health

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Office of Air Quality Control
Division of Technical Services
Washington State Department of Health

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Kansas Milk Network, January-December 1969

Radiation Control Section
Kansas State Health Department

The Radiation Control Section of the Kansas State Health Department maintains a program for analysis of pasteurized milk for strontium-89, strontium-90, and gamma-ray emitting radionuclides. Monthly milk samples are collected from six major consumption areas within Kansas. In addition, a sample is collected every other month in the Falls City, Nebr. area for the purpose of establishing baseline data to be used for environmental studies in connection with the commercial power reactor under construction at Brownville, Nebr. Brownville is located 22 miles north of the Kansas border. Figure 1 shows the various sampling sites. The Wichita and Kansas City samples are "split" samples which are analyzed by Kansas and the Public Health Service's Southwestern Radiological Health Laboratory (SWRHL).

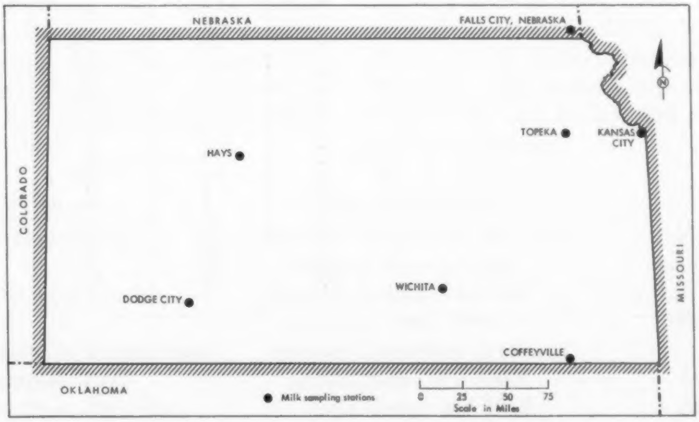

Figure 1. Kansas milk sampling stations

Table 1. Radionuclide and stable element concentration in Kansas pasteurized milk, 1969

Month	Location	Cesium-137 (pCi/liter)	Iodine-131 (pCi/liter)	Strontium-90 (pCi/liter)	Potassium-40 (pCi/liter)	Calcium (g/liter)
January	Dodge City	9	ND	6	1,121	1.1
	Coffeyville	13	6	9	997	1.2
	Hays	NS	NS	NS	NS	NS
	Kansas City	NS	NS	NS	NS	NS
	Falls City	9	1	2	1,150	1.1
	Topeka	9	4	6	993	1.2
	Wichita	NS	NS	NS	NS	NS
February	Dodge City	12	10	3	1,107	1.2
	Coffeyville	6	6	5	1,087	1.1
	Hays	3	3	4	1,103	1.2
	Kansas City	NS	NS	NS	NS	NS
	Falls City	NS	NS	NS	NS	NS
	Topeka	6	ND	5	1,042	1.1
	Wichita	NS	NS	NS	NS	NS
March	Dodge City	5	6	7	1,157	1.2
	Coffeyville	15	7	3	1,041	1.2
	Hays	NS	NS	NS	NS	NS
	Kansas City	NS	NS	NS	NS	NS
	Falls City	6	4	5	1,092	1.2
	Topeka	9	NS	12	958	1.2
	Wichita	NS	NS	NS	NS	NS
April	Dodge City	4	10	3	1,641	1.2
	Coffeyville	6	ND	4	1,050	1.1
	Hays	6	ND	2	1,038	1.2
	Kansas City	NS	NS	NS	NS	NS
	Falls City	NS	NS	NS	NS	NS
	Topeka	9	4	5	1,041	1.1
	Wichita	NS	NS	NS	NS	NS
May	Dodge City	4	ND	6	1,056	1.1
	Coffeyville	5	ND	9	976	1.1
	Hays	6	ND	5	1,028	1.1
	Kansas City	NS	NS	NS	NS	NS
	Falls City	7	ND	6	993	1.1
	Topeka	6	ND	11	930	1.1
	Wichita	NS	NS	NS	NS	NS
June	Dodge City	7	ND	11	913	1.1
	Coffeyville	7	8	17	1,011	1.1
	Hays	11	ND	9	982	1.0
	Kansas City	ND	ND	15	1,072	1.3
	Falls City	NS	NS	NS	NS	NS
	Topeka	6	3	15	1,008	1.0
	Wichita	12	ND	17	1,008	1.0
July	Dodge City	2	ND	14	1,203	1.1
	Coffeyville	10	ND	16	1,225	1.1
	Hays	13	ND	15	1,325	1.0
	Kansas City	1	ND	17	1,216	1.1
	Falls City	4	ND	18	1,304	1.1
	Topeka	7	ND	17	1,160	1.1
	Wichita	4	ND	14	1,304	1.0
August	Dodge City	8	ND	14	1,334	1.7
	Coffeyville	8	ND	12	1,287	1.0
	Hays	9	ND	15	1,250	1.0
	Kansas City	8	ND	12	1,275	1.3
	Falls City	NS	NS	NS	NS	NS
	Topeka	8	NS	17	1,267	1.0
	Wichita	8	ND	14	1,252	1.1
September	Dodge City	8	ND	8	1,344	1.1
	Coffeyville	1	ND	13	1,237	1.1
	Hays	8	10	14	1,261	1.1
	Kansas City	10	9	16	1,252	1.1
	Falls City	3	ND	19	1,200	1.1
	Topeka	6	ND	7	1,259	1.1
	Wichita	9	4	7	1,252	1.1
October	Dodge City	6	2	11	1,245	1.1
	Coffeyville	2	ND	13	1,171	1.1
	Hays	8	ND	7	1,179	1.2
	Kansas City	5	7	11	1,252	1.2
	Falls City	NS	NS	NS	NS	NS
	Topeka	8	2	13	1,212	1.1
	Wichita	6	2	11	1,244	1.1
November	Dodge City	8	6	14	1,208	1.1
	Coffeyville	9	7	13	1,297	1.1
	Hays	4	1	16	1,182	1.1
	Kansas City	6	9	21	1,276	1.1
	Falls City	3	ND	12	1,209	1.2
	Topeka	8	3	11	1,266	1.1
	Wichita	2	2	19	1,215	1.1
December	Dodge City	12	13	8	1,254	1.2
	Coffeyville	8	ND	11	1,208	1.1
	Hays	7	ND	9	1,197	1.1
	Kansas City	2	ND	9	1,163	1.1
	Falls City	NS	NS	NS	NS	NS
	Topeka	6	2	8	1,158	1.2

ND, nondetectable.
NS, no sample.

Analytical procedures

Each 3-1/2 liter sample is analyzed by gamma-ray scintillation spectrometry for barium-140, cesium-137, iodine-131, and potassium-40 (*1-2*). Strontium-89 and strontium-90 concentrations are determined radiochemically using ion exchange procedures (*3*). Chemical analyses for stable calcium have been made since 1968. Chemical analysis for potassium was begun in May 1970.

Results

Table I shows the stable element and radionuclide concentration in the Kansas pasteurized milk network for January–December 1969. No significant strontium–89 or barium–140 concentrations were found during this period except for the following barium–140 concentrations: September, Coffeyville, 11 pCi/liter; Kansas City, 16 pCi/liter; October, Hays, 11 pCi/liter; and December, Wichita, 14 pCi/liter.

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Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows.

Program	Period reported	Issue
California Diet Study	October–December 1968 and January–March 1969	May 1970
Connecticut Diet Study	July–December 1968 and January–June 1969	February 1970
Radionuclides in Institutional Diet Samples, *PHS*	October–December 1969 and annual summary 1969	August 1970
Strontium–90 in Tri-City Diets, *HASL*	June–December 1969	June 1970

SECTION II. WATER

The Public Health Service, the Federal Water Quality Administration and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligible small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	July–December 1968	August 1970
Minnesota	January–June 1969	January 1970
New York	January–June 1969	June 1970
North Carolina	January–December 1967	May 1969
Radiostrontium in Tap Water, *HASL*	January–December 1969	July 1970
Tritium Network	July–December 1969	July 1970
Washington	July 1967–June 1968	June 1969

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Radioactivity in Kansas Surface Waters, January-December 1969

Kansas State Department of Health
Radiological Health Section

Levels of radioactivity in the surface waters of Kansas are monitored by the Kansas State Department of Health, Radiation Control Section, in cooperation with the Radiological Laboratory and Water Data Analysis Section. This surveillance program is important because of both the present and future potential use of Kansas surface waters for domestic, recreational, and industrial purposes.

Liter samples are collected every month at each location shown in figure 1. These samples are analyzed for gross alpha and beta radioactivity. Radioactivity in these waters consists of the natural radioactivity picked up by flowing streams and percolating ground water, radioactivity from sewage discharge into the streams, and some contribution by industrial waste. The final contributing factor to radioactivity content is fallout, particularly over large expanses of open water, such as reservoirs and lakes.

Analytical procedures

Radioactivity analyses are performed by the Kansas Radiological Health Laboratory. Measurements of gross alpha-plus-beta radioactivity in total solids are made with a windowless-gas-flow proportional counter. Each sample is evaporated on an aluminum planchet, dried at 250° C., and then counted. Specific radionuclide analyses are made by gamma spectroscopy or chemical separation.

Discussion

Table 1 shows the gross alpha and gross beta radioactivity in the total solids in Kansas surface waters from January through December 1969. These waters are used for domestic, inindustrial, and recreational purposes.

At the present time, there is only one surface water sampling station in western Kansas, at Dodge City. This is partly because of the scarcity of surface water in this region. Plans for the future include the development of at least five sampling points in the western portion of the State.

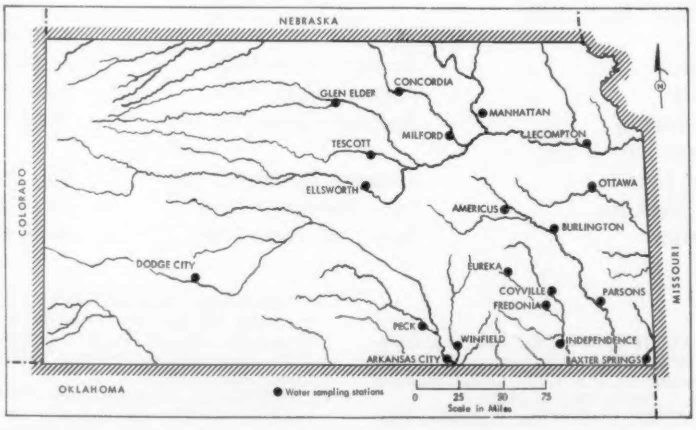

Figure 1. Kansas surface water sampling stations

Table 1. Gross radioactivity in Kansas surface waters, January–December 1969

Rivers	Sampling stations	Radioactivity concentration (pCi/liter)											
		January		February		March		April		May		June	
		Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
Arkansas	Arkansas City	ND	[a] 7	[a] 9	ND	[a] 3	[a] 53	ND	[a] 10	[a] 2	[a] 40	ND	[a] 10
	Dodge City	[a] 18	29	[a] 44	[a] 65	[a] 11	[a] 34	[a] 22	ND	[a] 2	[a] 60	[a] 2	93
Big Blue	Manhattan	[a] 6	[a] 15	ND	[a] 23	[a] 1	36	[a] 4	[a] 14	[a] 6	[a] 25	[a] 2	[a] 29
Fall	Eureka	[a] 11	[a] 21	ND	[a] 12	ND	[a] 28	[a] 2	[a] 4	ND	[a] 16	ND	35
	Fredonia	[a] 2	[a] 7	[a] 4	[a] 24	ND	[a] 9	[a] 10	[a] 5	ND	[a] 33	[a] 2	[a] 20
Kansas	Lecompton	NS	NS	ND	27	[a] 3	[a] 4	[a] 3	[a] 6	[a] 9	[a] 4	[a] 10	[a] 38
Marais Des Cygnes	Ottawa	[a] 5	[a] 15	[a] 8	[a] 26	[a] 4	[a] 31	NS	NS	NS	NS	NS	NS
Neosho	Americus	ND	ND	[a] 2	[a] 20	ND	[a] 32	[a] 1	ND	[a] 8	[a] 28	ND	[a] 2
	Burlington	ND	[a] 20	ND	[a] 16	ND	ND	[a] 1	[a] 21	[a] 6	15	NS	NS
	Parsons	[a] 4	[a] 14	ND	[a] 16	ND	[a] 5	ND	[a] 15	[a] 12	[a] 18	ND	[a] 20
Ninnescah	Peck	ND	[a] 1	ND	[a] 22	[a] 1	[a] 14	ND	ND	ND	[a] 20	[a] 7	ND
Republican	Concordia	[a] 13	[a] 18	NS	NS	[a] 10	[a] 26	[a] 4	42	[a] 6	[a] 10	[a] 7	[a] 22
	Milford	ND	[a] 32	NS	NS	[a] 10	[a] 33	[a] 6	[a] 15	ND	46	[a] 1	[a] 16
Saline	Tescott	[a] 23	[a] 36	ND	[a] 30	[a] 2	[a] 30	[a] 7	49	[a] 12	57	[a] 4	[a] 20
Smoky Hill	Ellsworth	[a] 2	31	[a] 10	52	[a] 10	[a] 15	[a] 9	[a] 34	[a] 6	[a] 4	[a] 3	[a] 19
Solomon	Glenn Elder	[a] 15	[a] 9	[a] 4	46	NS	NS	[a] 7	[a] 27	[a] 5	46	ND	55
Spring	Baxter Springs	ND	[a] 10	[a] 4	[a] 8	ND	[a] 5	ND	[a] 14	[a] 2	[a] 11	ND	[a] 37
Verdigris	Coyville	[a] 8	[a] 18	ND	41	[a] 3	[a] 9	[a] 1	ND	[a] 1	[a] 25	ND	[a] 18
	Independence	[a] 8	25	[a] 22	[a] 17	ND	[a] 2	[a] 9	[a] 20	[a] 5	[a] 2	ND	[a] 20
Walnut	Winfield	[a] 2	[a] 2	ND	[a] 10	[a] 2	[a] 5	ND	[a] 6	[a] 7	[a] 16	ND	[a] 26

Table 1. Gross radioactivity in Kansas surface waters, January–December 1969—(Continued)

Rivers	Sampling stations	Radioactivity concentration (pCi/liter)											
		July		August		September		October		November		December	
		Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
Arkansas	Arkansas City	[a] 30	54	6	[a] 31	1	[a] 46	[a] 13	ND	[a] 19	20	[a] 11	ND
	Dodge City	[a] 18	ND	[a] 39	[a] 31	[a] 40	ND	6	75	[a] 31	[a] 70	[a] 16	[a] 81
Big Blue	Manhattan	NS	NS	[a] 9	37	[a] 4	[a] 26	[a] 4	[a] 20	[a] 1	35	24	5
Fall	Eureka	[a] 3	[a] 18	[a] 5	[a] 9	ND	ND	[a] 1	[a] 16	[a] 6	[a] 11	ND	39
	Fredonia	ND	[a] 8	[a] 4	[a] 2	ND	ND	[a] 1	[a] 10	[a] 5	[a] 25	23	[a] 12
Kansas	Lecompton	ND	[a] 25	NS	NS	[a] 3	[a] 33	[a] 13	[a] 32	[a] 4	[a] 9	[a] 3	[a] 15
Marais Des Cygnes	Ottawa	[a] 6	[a] 14	NS	NS	[a] 1	[a] 28	[a] 1	[a] 23	[a] 9	[a] 34	[a] 2	ND
Neosho	Americus	ND	38	3	34	NS	NS	NS	NS	NS	NS	NS	NS
	Burlington	NS	NS	NS	NS	NS	NS	NS	NS	[a] 1	53	[a] 1	[a] 9
	Parsons	[a] 3	[a] 9	ND	[a] 6	[a] 2	[a] 19	[a] 1	[a] 19	[a] 4	[a] 20	ND	[a] 31
Ninnescah	Peck	[a] 2	[a] 9	ND	[a] 14	[a] 1	[a] 9	ND	[a] 24	[a] 4	46	NS	NS
Republican	Concordia	NS	NS	[a] 8	36	[a] 13	47	[a] 3	[a] 22	[a] 6	54	[a] 5	35
	Milford	[a] 2	[a] 24	[a] 5	[a] 18	[a] 10	[a] 16	[a] 2	[a] 12	[a] 8	51	NS	NS
Saline	Tescott	[a] 15	[a] 25	[a] 32	[a] 30	ND	[a] 50	[a] 17	[a] 4	[a] 4	[a] 38	[a] 1	[a] 55
Smoky Hill	Ellsworth	[a] 8	[a] 35	[a] 9	61	[a] 3	ND	[a] 2	ND	[a] 12	[a] 68	[a] 6	[a] 2
Solomon	Glenn Elder	[a] 4	[a] 18	[a] 14	[a] 22	[a] 13	55	ND	[a] 23	[a] 2	[a] 31	[a] 6	[a] 33
Spring	Baxter Springs	[a] 2	ND	NS	NS	[a] 2	ND	NS	NS	NS	NS	NS	NS
Verdigris	Coyville	ND	[a] 23	[a] 10	[a] 2	NS	NS	[a] 8	[a] 2	[a] 1	[a] 11	ND	[a] 9
	Independence	ND	[a] 7	[a] 5	[a] 32	ND	[a] 7	[a] 8	[a] 9	ND	[a] 20	[a] 2	[a] 10
Walnut	Winfield	[a] 2	[a] 24	[a] 13	[a] 25	[a] 3	[a] 5	ND	[a] 4	[a] 7	[a] 20	[a] 9	[a] 18

[a] When the counting rate of the sample is not equal to at least twice the 95-percent error, the value reported is not statistically significant but is the best available estimate. NS, no sample. ND, nondetectable.

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports*:

Network	Period	Issue
Fallout in the United States and Other Areas, *HASL*	January–June 1968	October 1969
Plutonium in Airborne Particulates and Precipitation, *PHS*	January–March 1969	August 1970

1. Radiation Alert Network
May 1970

National Air Pollution Control Administration
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 73 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel. On January 1, 1970, the operation of the RAN was transferred from the Bureau of Radiological Health to the National Air Pollution Control Administration (NAPCA). This transfer was completed in May 1970.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate NAPCA officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Data Acquisition and Analysis Branch, Division of Air Quality Emission Data, NAPCA, Cincinnati, Ohio. A detailed description of the sampling and analytical procedures was presented in the April 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during May 1970. Time profiles of gross beta radioactivity in air for eight Radiation Alert Network stations are shown in figure 2.

All field estimates reported were within normal limits for the reporting station.

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, May 1970

Station location		Air surveillance: Number of samples	Gross beta radioactivity (pCi/m³): Maximum	Minimum	Average[a]	Last profile in RHD&R	Precipitation: Number of samples	Total depth (mm)	Field estimation of deposition: Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	22	8	1	4	Dec 69	1	11	1	11	27
Alaska:	Adak	(b)				Oct 70	(c)				
	Anchorage	16	0	0	0	June 70	(c)				
	Attu Island	16	0	0	0	Jan 70	(c)				
	Fairbanks	16	2	0	1	July 70	3	13	3	13	8
	Juneau	(b)				Aug 70	(c)				
	Kodiak	1	0	0	0	Sept 70	(c)				
	Nome	31	2	0	1	Mar 70	(c)				
	Point Barrow	31	0	0	0	Feb 70	(c)				
	St. Paul Island	(b)				Apr 70	(c)				
Ariz:	Phoenix	11	4	2	3	Aug 70	(c)				
Ark:	Little Rock	10	4	1	2	June 70	(c)				
Calif:	Berkeley	21	1	0	0	Sept 70	(c)				
	Los Angeles	21	5	0	1	Mar 70	(c)				
C.Z:	Ancon	15	0	0	0	Sept 70	(c)				
Colo:	Denver	21	7	1	5	Sept 70	2	11	(d)		
Conn:	Hartford	20	2	0	1	July 70	7	64	7	64	11
Del:	Dover	20	1	0	1	May 70	(c)				
D.C:	Washington	24	1	0	1	Feb 70	(c)				
Fla:	Jacksonville	20	2	0	1	June 70	2	42	2	42	1
	Miami	19	1	0	0	July 70	4	108	3	58	0
Ga:	Atlanta	21	2	1	1	Apr 70	(c)				
Guam:	Agana	(b)				May 70	(c)				
Hawaii:	Honolulu	26	1	0	1	Jan 70	2	11	(d)		
Idaho:	Boise	19	4	1	2	Jan 70	4	25	4	25	6
Ill:	Springfield	19	5	1	2	Feb 70	(c)				
Ind:	Indianapolis	(b)				Apr 70	(c)				
Iowa:	Iowa City	14	4	0	2	Sept 70	5	116	5	116	14
Kans:	Topeka	20	4	1	2	June 70	5	68	5	68	4
Ky:	Frankfort	10	3	1	1	Feb 70	(c)				
La:	New Orleans	16	1	0	1	Feb 70	6	121	(d)		
Maine:	Augusta	20	2	0	1	Aug 70	9	278	9	278	0
Md:	Baltimore	20	1	0	1	July 70	4	34	4	34	13
	Rockville	17	3	0	1	Jan 70	(c)				
Mass:	Lawrence	19	1	0	1	Sept 70	4	82	4	82	1
	Winchester	19	2	0	1	Dec 69	4	82	4	82	0
Mich:	Lansing	20	2	0	1	Jan 70	8	71	8	71	10
Minn:	Minneapolis	21	4	0	1	May 70	8	148	8	148	37
Miss:	Jackson	18	3	0	1	Aug 70	1	71	1	71	0
Mo:	Jefferson City	20	3	0	1	Apr 70	8	205	8	205	4
Mont:	Helena	18	3	0	1	Dec 69	3	17	3	17	0
Nebr:	Lincoln	16	6	2	4	Apr 70	4	81	4	81	43
Nev:	Las Vegas	15	3	1	2	July 70	(c)				
N.H:	Concord	(b)				Feb 70	(c)				
N.J:	Trenton	19	3	0	1	Aug 70	7	92	7	92	15
N. Mex:	Santa Fe	11	3	0	2	Dec 69	1	7	1	7	0
N.Y:	Albany	5	1	0	1	Apr 70	3	22	3	22	6
	Buffalo	19	2	0	1	Sept 70	(c)				
	New York City	(b)				Dec 69	(c)				
N.C:	Gastonia	17	9	2	5	Sept 70	2	36	(d)		
N. Dak:	Bismarck	21	3	0	1	Feb 70	8	57	8	57	3
Ohio:	Cincinnati	(b)				May 70	(c)				
	Columbus	4	3	0	2	Aug 70	(c)				
	Painesville	16	2	1	1	July 70	8	71	8	71	28
Okla:	Oklahoma City	(b)				Jan 70	(c)				
	Ponca City	19	3	0	2	July 70	2	19	2	19	0
Ore:	Portland	19	1	0	0	Apr 70	5	37	5	37	2
Pa:	Harrisburg	14	2	0	1	Apr 70	1	20	1	20	2
P.R:	San Juan	(b)				Aug 70	(c)				
R.I:	Providence	20	2	0	1	Jan 70	(c)				
S.C:	Columbia	16	3	0	1	Dec 69	3	86	3	86	1
S. Dak:	Pierre	15	6	1	3	Aug 70	(c)				
Tenn:	Nashville	20	3	0	1	Jan 70	3	80	3	80	15
Tex:	Austin	14	4	1	2	May 70	(c)				
	El Paso	(b)				Feb 70	(c)				
Utah:	Salt Lake City	31	3	0	2	Mar 70	7	35	7	35	4
Vt:	Barre	19	3	0	1	June 70	7	66	7	66	8
Va:	Richmond	21	1	0	1	June 70	5	64	5	64	10
Wash:	Seattle	24	1	0	0	June 70	4	17	(d)		
	Spokane	20	2	0	2	May 70	(c)				
W. Va:	Charleston	19	3	0	2	Dec 69	4	48	4	48	5
Wisc:	Madison	21	3	0	1	June 70	8	79	8	79	16
Wyo:	Cheyenne	20	8	1	3	July 70	3	40	3	40	7
Network summary		1,127	9	0	1		4	65	5	67	9

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] No report received. (Air samples received without field estimate data are not considered by the data program.)
[c] No precipitation sample collected.
[d] This station is part of the plutonium in precipitation network. No gross beta measurements are done.
[e] Samples were collected but no field estimates were received.

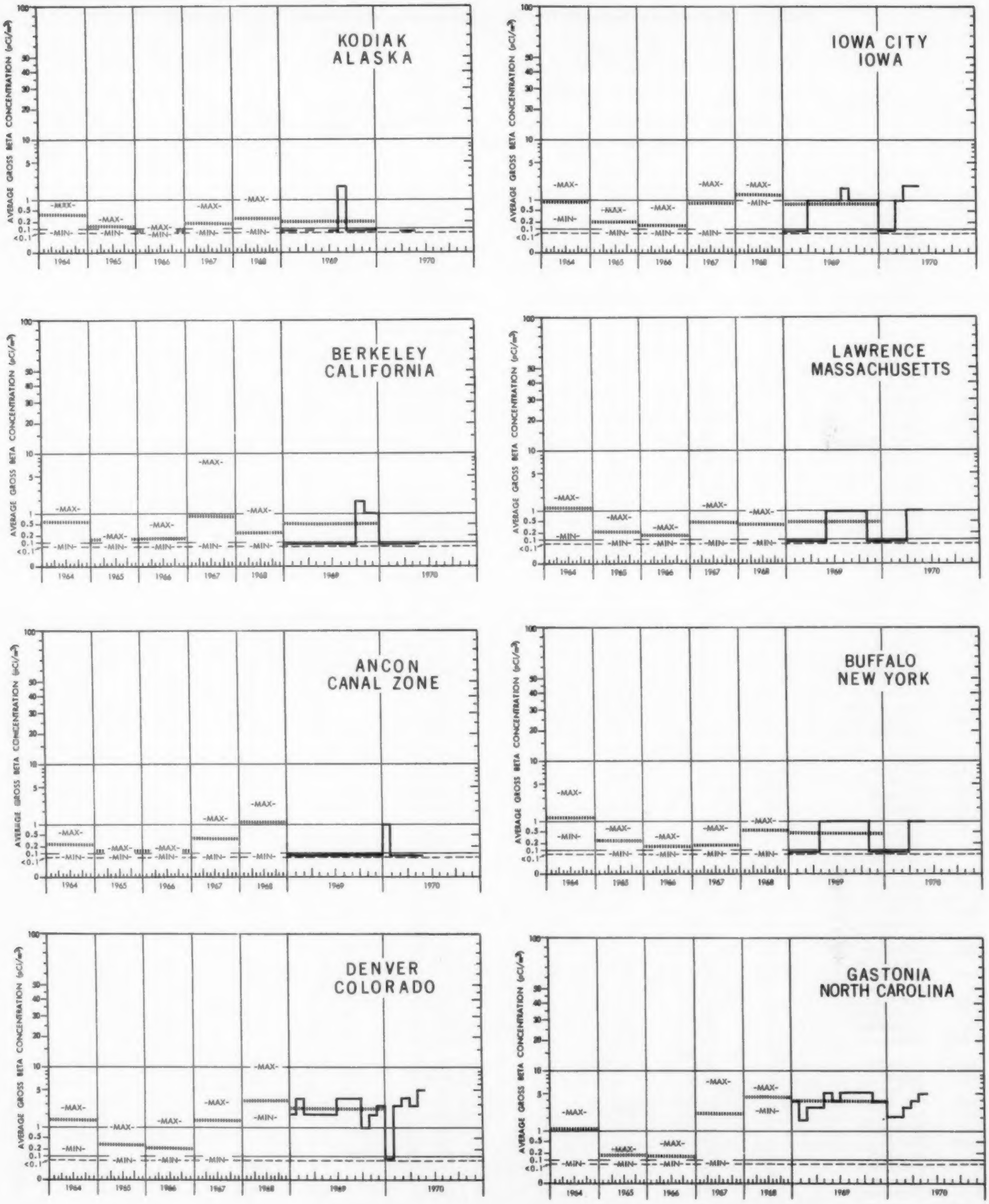

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Alert Network, 1964–May 1970

2. Canadian Air and Precipitation Monitoring Program,[1] May 1970

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports.*

[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Surface air and precipitation data for May 1970 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, May 1970

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	31	1.6	0.1	0.5	69	1.3
Coral Harbour	31	.2	.1	.1	119	.8
Edmonton	30	.6	.1	.3	222	3.3
Ft. Churchill	29	.3	.1	.2	299	2.9
Fredericton	29	.9	.0	.3	91	8.4
Goose Bay	30	.5	.0	.1	50	3.9
Halifax	18	.5	.0	.2	104	8.8
Inuvik	31	.4	.0	.1	177	2.6
Montreal	30	1.0	.1	.4	142	7.4
Moosonee	30	.9	.0	.3	77	3.9
Ottawa	31	.7	.1	.3	57	4.5
Quebec	31	.5	.0	.3	55	5.8
Regina	31	.6	.1	.3	136	6.9
Resolute	30	.2	.0	.2	75	.1
St. John's, Nfld	28	.5	.0	.2	19	2.1
Saskatoon	31	.6	.1	.3	313	4.1
Sault Ste. Marie	30	.6	.0	.3	59	10.4
Thunder Bay	29	.5	.0	.2	110	15.8
Toronto	31	.8	.0	.3	119	6.6
Vancouver	31	.5	.1	.2	110	2.9
Whitehorse	31	.3	.0	.1	130	3.1
Windsor	31	.6	.0	.3	20	1.7
Winnipeg	31	.6	.0	.3	185	16.0
Yellowknife	31	.5	.1	.2	25	.3
Network summary	716	1.6	0.0	0.3	115	5.2

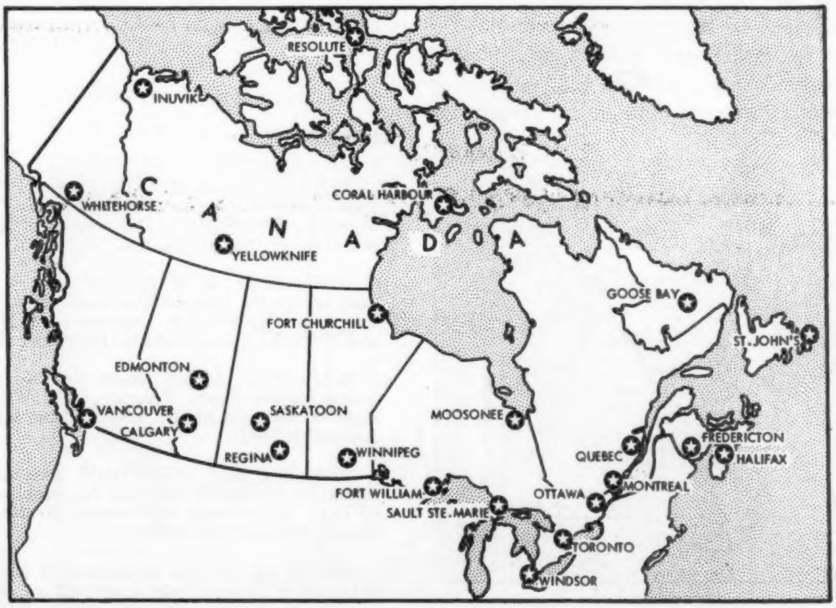

Figure 3. Canadian air and precipitation sampling stations

3. Pan American Air Sampling Program May 1970

Pan American Health Organization and
U.S. Public Health Service

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 4. Analytical techniques were described in the January 1968 issue of *Radiological Health Data and Reports*. The May 1970 air monitoring results from the participating countries are given in table 3.

Figure 4. Pan American Air Sampling Program stations

Table 3. Summary of gross beta radioactivity in Pan American surface air, May 1970

Station location		Number of samples	Gross beta radioactivity (pCi/m^3)		
			Maximum	Minimum	Average[a]
Argentina:	Buenos Aires	NS	NS	NS	NS
Bolivia:	La Paz	NS	NS	NS	NS
Chile:	Santiago	19	0.14	0.02	0.05
Colombia:	Bogota	28	.12	.00	.03
Ecuador:	Cuenca	NS	NS	NS	NS
	Guayaquil	23	.07	.01	.02
	Quito	NS	NS	NS	NS
Guyana:	Georgetown	1	.22	.22	.22
Jamaica:	Kingston	NS	NS	NS	NS
Peru:	Lima	29	.06	.01	.03
Venezuela:	Caracas	26	.69	.09	.30
West Indies:	Trinidad	([b])	—	—	—
Pan American summary		126	0.69	0.00	0.09

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m^3 are reported and used in averaging as 0.00 pCi/m^3.
[b] Motor failure.
NS, no sample.

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SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Strontium-90 in Human Bone, October-December 1969[1]

Bureau of Radiological Health
U.S. Public Health Service

To obtain data on the concentration of strontium-90 in man by age and geographical region, the Public Health Service began collecting human bone specimens in late 1961. Analyses of selected samples of people in older-age groups have shown their bone strontium-90 content to be low and age-independent (*1*). Consequently, the target population includes children and young adults up to 25 years of age.

Although a few samples come from living persons as a result of surgical procedures, the majority are obtained post mortem. In the latter case, the specimens are limited to accident victims or persons who have died of an acute disease process that was not likely to impair bone metabolism. For analytical purposes, a sample of at least 100 grams of wet bone is desired. Generally, this amount is readily available from older children, but it presents some difficulties from the standpoint of infants and children under 5 years of age. Most specimens received to date have been vertebrae and ribs.

[1] Period during which death or surgical procedure occurred.

Laboratory procedures

The bones are analyzed at the Northeastern Radiological Health Laboratory of the Bureau of Radiological Health, at Winchester, Mass. Sample collection and preparation are explained

Figure 1. Geographical regions for human bone sampling

Table 1. Strontium-90 in human bone, October–December 1969

Bone region and State	Bone type	Age[b] (years)	Sex	Strontium-90 concentration[c] (pCi/kg bone)	Calcium concentration (g/kg bone)	Sr/Ca (pCi/g)
Northeast:						
New York	V	9	M	57.8± 6.8	38.6	1.49
New Jersey	V	10	M	67.0± 8.0	36.2	1.85
New York	V	10	M	36.1± 7.9	27.1	1.33
	V	12	M	75.4± 8.7	52.6	1.43
	V	12	M	59.6± 7.0	36.3	1.64
	V	13	F	54.1± 5.9	31.2	1.73
	V	14	F	63.2±10.0	45.6	1.38
Rhode Island	S	15	M	47.8± 4.4	16.7	2.86
New York	V	18	M	73.9± 7.7	28.2	2.62
	V	20	F	98.9±10.0	55.2	1.79
	V	21	F	104.0± 8.8	57.5	1.80
	V	23	M	105.0±13.0	65.7	1.59
	V	23	M	44.7± 7.3	33.1	1.35
	V	24	M	53.5± 7.7	32.2	1.66
Rhode Island	S	25	M	12.2± 2.2	11.0	1.10
Southeast:						
North Carolina	V	7	M	37.4± 5.3	26.5	1.41
South Carolina	V	7	M	88.3± 8.5	30.2	2.92
	V	7	F	77.1±10.0	26.7	2.88
	V	14	M	118.0±13.0	45.7	2.58
Maryland	V	14	M	172.0±15.0	72.3	2.37
South Carolina	V	16	M	148.0±12.0	48.5	3.05
Maryland	V	17	F	90.9± 9.5	47.0	1.93
Georgia	V	17	F	88.5±10.0	44.4	1.99
Maryland	V	18	F	89.3±13.0	67.6	1.32
	V	18	F	130.0±12.0	46.2	2.81
South Carolina	V	18	F	102.0± 9.5	50.7	2.01
Maryland	V	18	M	80.9± 9.2	52.2	1.54
	V	18	M	99.6± 9.0	54.8	1.81
	V	19	F	115.0±12.0	54.3	2.11
	V	19	F	41.7± 7.3	40.6	1.02
South Carolina	V	19	M	160.0±12.0	53.5	2.99
Maryland	V	20	M	126.0±12.0	53.2	2.36
	V	20	M	71.0± 9.9	50.9	1.39
	V	20	M	118.0±12.0	56.1	2.10
	V	20	F	55.9± 7.6	40.8	1.37
South Carolina	V	21	M	63.6± 8.9	40.4	1.57
Maryland	V	21	M	80.7±10.0	52.8	1.52
	V	22	M	87.4± 8.6	44.2	1.97
	V	22	M	82.2± 9.1	60.2	1.36
	V	23	M	129.0±11.0	67.4	1.91
	V	23	M	73.4± 7.7	43.6	1.68
Tennessee	V	25	M	31.7± 6.9	43.6	.72
Central:						
Ohio	V	0	M	153.0±14.0	66.8	2.29
Wisconsin	V	2	F	47.4± 7.1	28.0	1.69
Iowa	V	3	F	36.6± 6.0	23.7	1.54
Wisconsin	V	3	F	116.0±12.0	55.0	2.10
	V	4	M	55.3± 7.9	28.5	1.94
Ohio	V	8	M	79.1±10.0	51.1	1.54
Wisconsin	V	8	F	82.3± 8.6	34.0	2.42
Ohio	V	10	M	99.7±10.0	38.2	2.60
	V	11	F	81.6± 8.7	51.3	1.59
	V	13	F	138.0±13.0	59.8	2.30
	V	14	M	72.8± 7.9	39.2	1.85
Michigan	V	15	M	145.0±15.0	62.5	2.32
Ohio	V	15	F	107.0±13.0	62.0	1.72
	V	15	M	84.7± 9.7	56.8	1.49
	V	16	F	109.0±11.0	56.0	1.94
Michigan	V	16	M	192.0±15.0	65.5	2.93
Ohio	V	17	M	110.0± 9.5	47.3	2.32
	V	17	F	95.9±12.0	59.7	1.60
	V	18	M	162.0±14.0	60.7	2.66
	V	18	M	242.0±18.0	61.0	3.96
	V	18	M	77.6± 8.7	51.8	1.49
Minnesota	V	18	F	73.6± 7.7	50.0	1.47
Ohio	V	18	M	115.0±13.0	62.4	1.84
	V	19	M	146.0±10.0	51.3	2.84
	V	19	M	209.0±16.0	63.8	3.27
Minnesota	V	19	F	70.4± 8.8	46.2	1.52
Ohio	V	20	M	72.3± 9.8	53.1	1.36
	V	21	M	94.3± 9.1	56.4	1.67
	V	21	M	95.4±11.0	60.8	1.56
	V	21	M	152.0±15.0	76.8	1.97
	V	21	M	101.0±27.0	51.3	1.96
	V	22	M	139.0±12.0	68.0	2.04
	V	22	M	97.5±12.0	63.7	1.53
Minnesota	V	22	M	62.9± 8.6	45.9	1.37
Ohio	V	22	M	82.3±11.0	59.9	1.37
	V	23	M	91.0±12.0	61.2	1.48
	V	23	M	89.7±14.0	61.0	1.47
	V	23	F	64.7± 9.7	52.8	1.22
Michigan	V	24	M	102.0± 9.1	63.3	1.61
Ohio	V	24	M	83.7±11.0	53.5	1.56
Michigan	V	25	F	95.0± 8.6	49.8	1.90

See footnotes at end of table.

Table 1. Strontium-90 in human bone, October-December 1969—Continued

Bone region and State	Bone type	Age: (years)	Sex	Strontium-90 concentration: (pCi/kg bone)	Calcium concentration (g/kg bone)	Sr/Ca (pCi/g)
Delta:						
Louisiana	V	9	F	103.0± 8.1	41.1	2.50
	V	15	M	138.0±13.0	50.2	2.74
	V	20	M	92.4±13.0	48.5	1.90
	V	20	F	96.0± 8.9	60.9	1.57
	V	25	M	85.8± 7.9	52.0	1.65
Northwest:						
Oregon	V	0	M	83.6± 9.9	49.6	1.68
	V	11	M	79.3± 6.9	36.9	2.14
Washington	V	16	M	126.0±10.0	40.4	3.11
Oregon	V	16	M	57.4± 6.3	43.4	1.32
	V	17	M	128.0±11.0	54.0	2.37
	V	18	M	71.9± 9.5	44.3	1.62
	V	19	M	91.3±11.0	38.5	2.37
	V	20	M	71.2± 9.7	47.8	1.48
	V	21	M	81.2±10.0	50.1	1.62
	V	23	F	52.0± 6.3	50.1	1.03
	V	24	F	39.1± 5.5	41.5	.94
Southwest:						
Colorado	V	21	M	64.5± 8.2	47.7	1.35
	V	21	M	18.5± 7.5	46.2	.40
	V	23	M	72.9± 9.9	62.0	1.17
	V	23	M	74.5± 8.5	53.6	1.38
North:						
Alaska	V	0	F	20.1± 8.9	13.7	1.46
	V	9	F	70.2± 5.6	29.3	2.39
	V	12	M	31.4± 5.1	22.6	1.38

[a] Type of bone, V, vertebrae; R, rib; S, sternum; T, tibia; F, femur.
[b] Age given as of last birthday prior to death.
[c] Two-sigma counting error.

elsewhere (*2*). Strontium-90 is measured by tributyl phosphate extraction of its yttrium daughter, which is precipitated as an oxalate. The strontium-90 content is then calculated (*3*) from the yttrium-90 activity. For the purpose of maintaining analytical reproducibility, "blind" duplicate analyses are performed on 10 to 20 percent of the samples.

The analytical results for strontium-90 in individual bones from persons dying during the fourth quarter (October-December) of 1969 are presented in table 1 in order of increasing age within each geographical region. These regions are indicated in figure 1. Reported values are given in picocuries of strontium-90 per kilogram of bone (as a rough indication of dose) and per gram of calcium (for comparison with other data and for purposes of model development). Two-sigma counting errors are reported for the bone concentration.

Following the pattern of earlier reports, subsequent articles will continue to provide interpretation of the data at appropriate stages in the program (*2–6*).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–March 1969	March 1970
April–June 1969	May 1970
July–September 1969	June 1970

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Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summaries of the environmental radioactivity data follow for the Bettis Atomic Power Laboratory, Los Alamos Scientific Laboratory and the Paducah Plant.

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Bettis Atomic Power Laboratory[2] January–December 1969

Westinghouse Electric Corporation
Pittsburgh, Pa.

The Bettis Atomic Power Laboratory (BAPL), operated for the Atomic Energy Commission by the Westinghouse Electric Corporation, was established in 1949 to conduct research and development operations related to naval atomic propulsion systems and to the central station power reactor at Shippingport, Pa. Routine environmental monitoring data from the sampling locations shown in figure 1 show no significant contribution from laboratory operations to environmental radioactivity levels.

Gaseous radioactive waste

The release of gaseous radioactive waste is monitored by continuous air sampling to assure compliance with laboratory regulations. The stack gas limits for the laboratory are based on the 168-hour nonoccupational maximum permissible concentrations in air as specified in AEC Manual Chapter 0524. At no time during 1969 did the concentration of stack releases exceed the required limits. The general public outside the boundary of the laboratory was not exposed to radiation above normal background levels as a result of operations at Bettis.

Total gaseous radioactivity released to the environment during 1969 was 1.88 mCi alpha and less than 189 mCi beta-gamma. Due to an increased volume of air discharged, the total radioactivity was greater than last year's quantities; the average concentration of radioactivity, however, remained the same.

Liquid radioactive waste

Radioactive liquids generated in the main laboratory and critical facility areas are collected in retention tanks and sampled for radioanalysis. The laboratory discharge limit of 2,000 pCi/liter is in compliance with AEC Manual Chapter 0524. If radioactivity of liquid wastes is greater than the discharge limit, the water is processed by ion exchange or evaporation. Water less than the discharge limit is released to the storm sewer and diluted with laboratory coolant water, process water, and surface runoff water. This plant effluent is discharged from laboratory property at the three locations shown in figure 1. A composite of the main laboratory effluent released at location 1 is collected and analyzed weekly for gross radioactivity. Critical facility effluent suitable for release is discharged at locations 2 and 3.

The plant effluent water analysis data is summarized in table 1. This shows that the average concentration of the laboratory effluent water is well below the discharge limit of 2,000 pCi/liter. Total radioactivity discharged from Bettis Laboratory during 1969 was 20.3 millicuries which was significantly less than the 90.3 millicuries released during 1968.

[2] Summarized from "Bettis Atomic Power Laboratory, Environmental Monitoring Report, Calendar Year 1969" (WAPD-CL(RA)E-109).

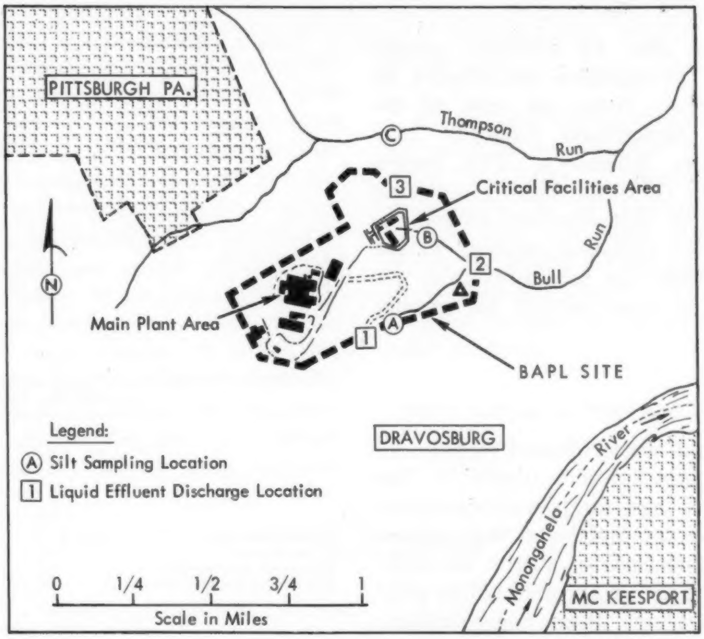


Figure 1. Bettis Atomic Power Laboratory sampling stations

Table 1. Average concentration of radioactivity in the Bettis Laboratory liquid effluent, January–December 1969[a]

Month 1969	Main laboratory			Critical facility		
	Gross radioactivity (pCi/liter)		Volume (10^6 gallons)	Gross radioactivity (pCi/liter)		Volume (10^3 gallons)
	Beta-gamma	Alpha		Beta-gamma	Alpha[b]	
January–March	47	5.5	36.4	1,400	<240	0.63
April–June	21	2.4	44.8	1,100	<240	3.7
July–September	21	2.4	40.4	1,200	350	18.0
October–December	25	13.0	38.1	—	—	0
Summary	28	5.7	159.7	1,200	330	22.33

[a] Discharge limit 2,000 pCi/liter gross radioactivity. The criteial facility effluent is just monitored process water whereas the main laboratory effluent inclubes the complete storm sewer flow.
[b] Minimum detectable level for alpha radioactivity for the analytical technique used is 240 pCi/liter.

The average concentrations of gross beta-gamma radioactivity in the main laboratory liquid effluent during 1969 was 28 pCi/liter. This was lower than the average concentration of 120 pCi/liter observed for the year 1968.

Average radioactivity in liquid waste effluent from the critical facility operations during 1969 were: alpha radioactiviy, <330 pCi/liter; beta-gamma radioactivity, 1.2 nCi/liter. Comparable values for 1968 were 610 pCi/liter for alpha radioactivity and 1.00 nCi/liter for beta-gamma radioactivity.

Background monitoring stations

Background beta-gamma radiation levels were continuously monitored and recorded at 34 film badge monitoring stations located along the perimeter fence of the laboratory which lies within the controlled confines of the Bettis Atomic

Power Laboratory site. In addition, control badges are placed at locations not affected by laboratory operations. These are used to determine the net background radiation level contributed by the laboratory. The results obtained from the environmental monitoring film badges posted at these locations around the laboratory show that radiation exposure to the general public outside the laboratory was not above that received from natural background radiation levels.

Stream silt

Stream silt samples were collected periodically at the three discharge locations (figure 1). The results of analysis of these samples are presented in table 2. The average alpha and beta-gamma radioactivity concentrations of stream silt samples for 1969 were 17.86 pCi/g and 123.95 pCi/g, respectively. Although these concentrations represent an increase over those for 1968, they are consistent with concentrations detected in previous years.

Semiannual analyses for strontium-89 and strontium-90 were obtained for composites of silt samples. Table 3 presents the results of these analyses for samples collected during 1969.

Table 2. Radioactivity in stream silt, Bettis, 1969

Location	Number of samples	Radioactivity (pCi/g)			
		Alpha		Beta-gamma	
		Range	Average	Range	Average
Bull Run Stream	20	<11–79	20.5	36–436	187
C-Area Stream	10	<11–27	14.1	18–83	51
Thompson Run Stream	10	<11–33	15.8	41–116	71
Streets Run (Control Stream)	6	7–26	16.2	32–124	73

Table 3. Strontium-89 and strontium-90 in stream silt, Bettis, 1969

Location	Concentration (pCi/g of silt)	
	Strontium-89	Strontium-90
Bull Run Stream	0.93	0.59
C-Area Stream	1.04	.20
Thompson Run Stream	1.42	.14
Streets Run (Control Stream)	.29	.29

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–December 1967	March 1969
January–December 1968	January 1970

2. Los Alamos Scientific Laboratory[3] January–December 1969

University of California
Los Alamos, N. Mex.

As part of the environmental monitoring program at Los Alamos, measurements of beta radioactivity in airborne particulates and precipitation are made periodically. The samples have been taken on the roof of building TA-50 (about 1 3/4 miles southeast of the administration building) since March 1963.

[3] Summarized from "Beta Radioactivity in Environmental Air and Precipitation at Los Alamos, New Mexico, for 1969" (LA-4388).

Air monitoring

Airborne radioactive particulate matter is collected on 4-inch-diameter filters. The air sampling rate is 25.5 m^3/h. Air samples are ordinarily collected for 24-hour intervals during the work week, and weekend samples are collected for a 72-hour period.

The filters are counted for beta radioactivity 7 days after collection in a thin-window gas (methane) flow proportional counter with an overall efficiency of 50 percent for strontium-yttrium-90.

Precipitation monitoring

Collection is made in a 0.4 square meter rain collector which delivers 1 liter of water for each

0.1 inch of precipitation. It has been found that this arrangement collected radioactivity even during relatively dry periods. By washing down the sides of the collector with 1 liter of distilled water, a suitable sample is obtained. Samples are taken daily on workdays. These "wash" samples, as well as any precipitation, are reduced in volume, dry-plated on 1-inch stainless-steel planchets, and counted in an automatic beta-particle system, employing a gas-flow proportional, alpha and beta chamber. A cosmic-ray umbrella with coincidence counter cancel provides a low background for the system. The counting efficiency is determined with a radiolead standard which emits 1.17 MeV beta particles.

Results

Average daily radioactivity concentrations for air collected are weighted for sample periods of more than 1 day. Average radioactivity concentrations for the precipitation collection are calculated from the total radioactivity collected during the month divided by the number of days in the month. Summary of air and precipitation data for January to December 1969 are summarized in table 4.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
1968	September 1969

Table 4. Beta radioactivity in air and precipitation, Los Alamos January–December 1969

Month 1969	Air (pCi/m³)			Precipitation (pCi/m²)			
	Maximum	Minimum	Average	Maximum	Minimum	Average	Total
January	0.11	<0.01	0.05	0.086	0.001	0.021	0.644
February	.17	.03	.08	.349	.003	.038	1.065
March	.27	.03	.08	.166	.003	.036	1.118
April	.38	.09	.20	2.237	.007	.243	7.304
May	.47	.06	.29	6.958	.030	.434	13.048
June	.49	.21	.37	3.723	.031	.666	19.980
July	.27	.06	.13	.969	.004	.173	5.391
August	.18	.04	.08	.518	.025	.119	3.699
September	.17	.03	.07	.274	.004	.080	2.407
October	.26	< .01	.10	.678	.008	.129	3.991
November	.17	.04	.06	.070	.004	.021	.624
December	.08	< .01	.05	.099	.002	.021	.640

3. Paducah Plant[4] July–December 1969

Union Carbide Corporation Paducah, Ky.

The Paducah Plant is a government-owned gaseous diffusion plant operated by the Nuclear Division of the Union Carbide Corporation for the Atomic Energy Commission. The diffusion plant processes large quantities of relatively pure uranium compounds. The uranium hexafluoride manufacturing plant, a former source of diffusion plant feed which was placed on standby in June of 1964, was reactivated in August 1968. Parts of the associated uranium metal foundry, usually on standby, are operated infrequently as the need arises. A decontamination and uranium recovery facility operates to prepare equipment for repair and to recover impure or scrap uranium materials. Depleted uranium metal is fabricated into shields, weights, ballasts, or other shapes on a nonroutine basis. The major sources of external penetrating radiation are the daughter products of uranium, thorium-234, and protactinium-234, which may be concentrated by uranium recovery processes or by uranium hexafluoride vaporization. The element uranium can be a physiological hazard only if allowed to enter the body. The chemical toxicity of the uranium processed at the Paducah Plant overshadows any probable biological effects of radiation from this element, thus making it comparable as a physiological hazard to lead, mercury, or other well-known heavy metals.

[4] Summarized from "Environmental Concentrations of Radioactive Materials near the Paducah Plant—Report for the Year and the Second Half of 1969."

The uranium enrichment areas (Cascade) operate with a very low loss of material. Millions of pounds of uranium hexafluoride may be fed to, diffused in, and withdrawn from the cascade with the loss of only a few pounds per year. There is a slight loss of uranium to the atmosphere when diluent gases are purged from equipment units or from the cascade. Some uranium on cascade equipment replaced for maintenance or modification is removed in the decontamination facility.

Effluents from the uranium hexafluoride manufacturing plant are more significant than those of the diffusion cascade. The transfer of powdered uranium salts between the numerous processing reactors and intermediate storage facilities requires extensive use of vacuum or local exhaust systems. Various bag and pleated filter units are used to remove uranium from exhaust air. The product uranium hexafluoride is separated from entrained solids, excess fluorine, and diluent gases by a series of filters, cold condensers, and fluid bed absorbers. A small fraction of the input to this plant constituting a significant amount of uranium is not reacted to uranium hexafluoride and must be processed through uranium recovery at the decontamination facility. Beta radioactive uranium decay products which separate from the uranium hexafluoride at fluorination are also in this material flow.

The environmental monitoring program provides for continuously sampling the air at four stations around the plant perimeter fence, and at five stations located approximately 1 mile outside this fence (figure 2). Big and Little Bayou Creek waters are sampled continuously, and grab samples are collected at five locations in the Ohio River and at the mouth of the combined Bayou Creeks. In addition, gamma radiation readings are taken each month at each of the air sampling stations with a Geiger-Mueller type meter at a distance of 3 feet above ground level.

Basic standards

The radiation protection standards observed at the Paducah Plant for exposure to radiation and radioactive materials, both for the in-plant work environment of employees and for offsite exposure of the general population, are those contained in Appendix 0524 of the AEC manual.

The standards specify that the radiation or radioactive materials outside a controlled area, and which have resulted from operations within that controlled area, shall be such that is it improbable that any individual may receive a dose of external radiation greater than 0.5 rem in any year and that the average exposure of a suitable population sample may not exceed one-third of this dose. To meet this standard, the average concentration of radionuclides in air or water beyond a controlled area should not exceed one-tenth of the maximum permitted for occupational exposure of 168 hours per week. For the purposes of such control, the concentrations of such radio-

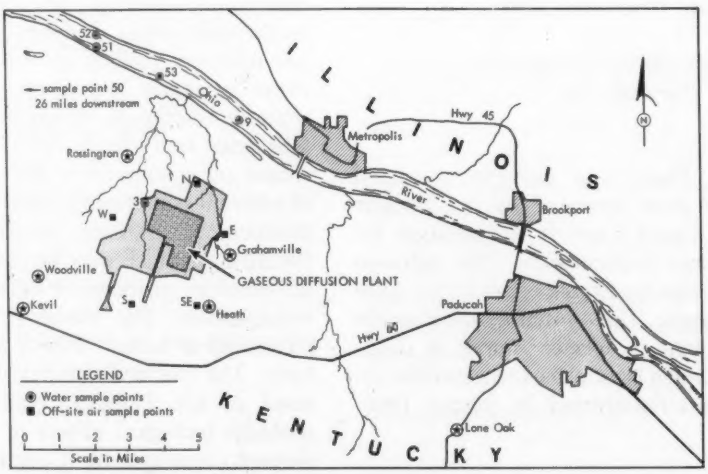


Figure 2. Sampling locations, Paducah Gaseous Diffusion Plant

nuclides in air or water may be averaged over periods of time up to 1 year.

Discussion

Data summarizing the environmental concentrations of radioactive materials in air and water and the gamma radiation levels in the vicinity of the Paducah Gaseous Diffusion Plant are presented in tables 5 through 9.

Table 5. Uranium concentrations in outdoor air samples, Paducah Plant, July–December 1969

Sample locations[a]	Number of samples	Uranium alpha radioactivity[b] (pCi/m³)		
		Maximum	Minimum[c]	Mean[d]
At plant perimeter fence:				
North	26	0.11	<0.02	0.03
East	26	.14	< .02	.03
South	26	.04	< .02	.01
West	26	.07	< .02	.02
All locations	104	0.14	<0.02	0.02
About 1 mile outside plant perimeter fence:				
North	26	0.04	<0.02	0.01
East	26	.06	< .02	.01
South	26	.05	< .02	.01
West	26	.03	< .02	.01
Southeast	26	.05	< .02	.01
All locations	130	0.06	<0.02	0.01

[a] See figure 2.
[b] As defined in NBS Handbook 69, paragraph 3.2, a microcurie of recently extracted normal uranium corresponds to 7.57×10^4 alpha dis/sec.
[c] The minimum detectable concentration of uranium in air is 0.02 pCi/m³.
[d] The AEC standard for natural uranium in air released to the environs beyond a controlled area is 2 pCi/m³.

Table 6. Beta radioactivity in outdoor air samples Paducah Plant, July–December 1969

Sample locations[a]	Number of samples	Beta radioactivity (pCi/m³)		
		Maximum	Minimum[b]	Mean[c]
At plant perimeter fence:				
North	26	3.9	<0.1	1.0
East	26	2.0	< .1	.59
South	26	.86	< .1	.27
West	26	1.9	< .1	.44
All locations	104	3.9	<0.1	0.59
About 1 mile outside plant perimeter fence:				
North	26	.59	<0.1	.21
East	26	.32	< .1	.14
South	26	.50	< .1	.19
West	26	.54	< .1	.22
Southeast	26	.50	< .1	.21
All locations	130	0.59	<0.1	0.19

[a] See figure 2.
[b] The minimum detectable amount of beta-particle emitters in air is 0.1 pCi/m³.
[c] The AEC standard, applicable to this table is 1×10^3 pCi/m³, which is the concentration limit of thorium-234, the daughter product of uranium-238. Insignificant amounts of other daughters are present in freshly refined uranium.

Air samples were collected continuously at each of the four stations at the plant perimeter fence and at five stations about 1 mile outside the plant. Air is filtered at 0.3 cfm through 2-inch diameter membrane filters which are replaced weekly and counted for alpha and beta radioactivity.

Table 7. Concentrations of uranium in water, Paducah Plant, July–December 1969

Sample locations[a]	Number of samples	Uranium[b] (pCi/liter)		
		Maximum	Minimum[c]	Mean[d]
Little Bayou 17	26	420	4	81
Big Bayou	26	21	<1	3
Mouth of Bayou 3 Creeks 21	6	1	<1	<1
Ohio River 9	6	<1	<1	<1
Composite of 50, 51, 52 and 53	6	<1	<1	<1

[a] See figure 2.
[b] As defined in NBS Handbook 69, paragraph 3.2, a microcurie of recently extracted normal uranium corresponds to 7.57×10^b alpha dis/sec.
[c] The minimum detectable concentration of uranium in water is 1 pCi/liter.
[d] The AEC standard for natural uranium in air released to the environs beyond a controlled area is 2 pCi/m³.

Table 8. Concentration of beta-particle emitters in water, Paducah Plant, July–December 1969

Sample locations[a]	Number of samples	Beta-particle emitters (pCi/liter)		
		Maximum	Minimum[b]	Mean
Little Bayou 17	26	38,000	<100	2,100
Big Bayou 3	26	100	<100	<100
Mouth of Bayou Creeks 21	6	<100	<100	<100
Ohio River 9	6	<100	<100	<100
Composite of 50, 51, 52 and 53	6	<100	<100	<100

[a] See figure 2.
[b] The minmum detectable amount of beta-particle emitters in water is 100 pCi/liter.
[c] The AEC standard for the immediate daughter products of uranium in water released to the environs is 2×10^4 pCi/liter. An increase in beta radioactivity in water, occurring during February and March 1969, was determined to be due to technetium-99 from the recovery operation of cylinder-wash solutions. The AEC standard for technetium-99 in water beyond a controlled area is 2×10^5 pCi/liter.

The average alpha-particle count—interpreted as uranium, the most likely source of radioactivity—of the 104 and the 130 air samples collected during the first half of 1969 at the perimeter fence and 1 mile, respectively, were 1.0 percent and 0.5 percent for the July–December period and for the year 1969 were 1 percent and 0.5 percent of the AEC standard set for individuals residing in the vicinity of a controlled area. The average beta-particle count of these samples was 0.06 of the standard at the perimeter fence and 0.02 percent of the standard at 1 mile.

Table 9. External gamma radiation levels Paducah, July–December 1969

Sample location[a]	Number of readings	Gamma radiation (mR/h)
At plant perimeter fence:		
North	5	0.02
East	5	.05
South	5	.02
West	5	.02
All locations	20	0.03
About 1 mile outside plant perimeter fence:		
North	5	0.02
East	5	.02
South	5	.02
West	5	.02
Southeast	5	.02
All locations	25	0.02

[a] See figure 2.

The average uranium analyses of weekly water samples collected continuously from Big and Little Bayou Creeks were 0.02 and 0.41 percent, respectively, of the AEC standard for water beyond a controlled area, during the second half of 1969; they were 0.03 and 0.33 percent, respectively, for the year 1969. The average of 11 grab samples taken in the mouth of the combined Bayou Creeks for the year of 1969 was less than 0.01 percent of the AEC standard, the identical figure for the mean analysis for the July–December period. The results of the uranium analyses for each of 11 grab samples collected at monthly intervals from the Ohio River below the plant was less than 0.01 percent of the AEC standard.

The concentration of beta-particle emitters in the Big and Little Bayou Creeks averaged less than 5 percent and 11 percent, respectively, of the AEC standard for the decay products of uranium–238 during July–December 1969 and less than 5 percent and 20 percent, respectively, for 1969. At the mouth of the combined Bayou Creeks, this average was less than 0.5 percent. The beta radioactivity of the Ohio River was below the standard during July–December 1969 and for the year averaged less than 0.5 percent of the standard for uranium–238 decay products.

External gamma radiation in the vicinity of the Paducah Plant averaged 0.02 mR/h at all sampling stations for July–December 1969, except for the east plant perimeter station, which had an average of 0.05 mR/h.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1968	July 1969
January–June 1969	April 1970

Reported Nuclear Detonations, August 1970

(Includes seismic signals from foreign test areas)

There were no nuclear detonations or seismic signals repored by the U. S. Atomic Energy Commission for August 1970.

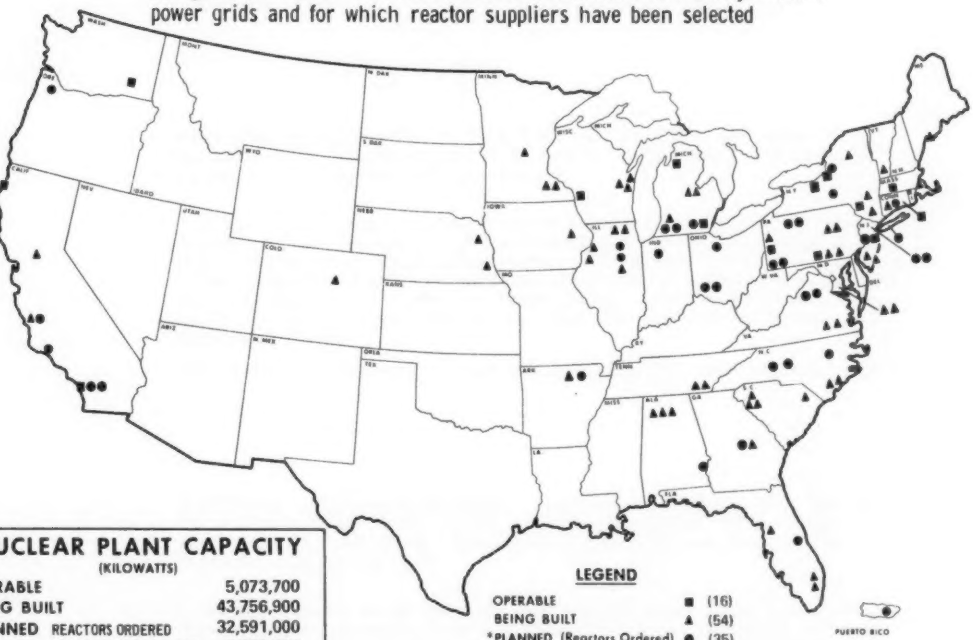
SITE	PLANT NAME	CAPACITY (Kilowatts)	UTILITY	INITIAL DESIGN POWER
ALABAMA				
Decatur	Browns Ferry Nuclear Power Plant: Unit 1	1,064,500	Tennessee Valley Authority	1971
Decatur	Browns Ferry Nuclear Power Plant: Unit 2	1,064,500	Tennessee Valley Authority	1972
Decatur	Browns Ferry Nuclear Power Plant: Unit 3	1,064,500	Tennessee Valley Authority	1972
Dothan	Joseph M. Farley Nuclear Plant	829,000	Alabama Power Co.	1975
ARKANSAS				
London	Arkansas Nuclear One: Unit 1	850,000	Arkansas Power & Light Co.	1973
London	Arkansas Nuclear One: Unit 2	950,000	Arkansas Power & Light Co.	1976
CALIFORNIA				
Humboldt Bay	Humbolt Bay Power Plant: Unit 3	68,500	Pacific Gas & Electric Co.	1963
San Clemente	San Onofre Nuclear Generating Station: Unit 1	430,000	So. Calif. Ed. & San Diego Gas & El. Co.	1967
San Clemente	San Onofre Nuclear Generating Station: Unit 2	1,140,000	So. Calif. Ed. & San Diego Gas & El. Co.	1975
San Clemente	San Onofre Nuclear Generating Station: Unit 3	1,140,000	So. Calif. Ed. & San Diego Gas & El. Co.	1977
Corral Canyon	Malibu Nuclear Plant: Unit 1	462,000	L.A. Dept of Water & Power	1975
Diablo Canyon	Diablo Canyon Nuclear Power Plant: Unit 1	1,060,000	Pacific Gas & Electric Co.	1973
Diablo Canyon	Diablo Canyon Nuclear Power Plant: Unit 2	1,060,000	Pacific Gas & Electric Co.	1974
Clay Station	Rancho Seco Nuclear Generating Station	800,000	Sacramento Municipal Utility District	1972
COLORADO				
Platteville	Ft. St. Vrain Nuclear Generating Station	330,000	Public Service Co. of Colorado	1972
CONNECTICUT				
Haddam Neck	Haddam Neck Plant	575,000	Conn. Yankee Atomic Power Co.	1967
Waterford	Millstone Nuclear Power Station: Unit 1	652,100	Northeast Utilities	1970
Waterford	Millstone Nuclear Power Station: Unit 2	828,000	Northeast Utilities	1974
FLORIDA				
Turkey Point	Turkey Point Station: Unit 3	651,500	Florida Power & Light Co.	1971
Turkey Point	Turkey Point Station: Unit 4	651,500	Florida Power & Light Co.	1972
Red Level	Crystal River Plant: Unit 3	858,000	Florida Power Corp.	1972
Ft. Pierce	Hutchinson Island	800,000	Florida Power and Light Co.	1973
GEORGIA				
Baxley	Edwin I. Hatch Nuclear Plant: Unit 1	786,000	Georgia Power Co.	1973
Baxley	Edwin I. Hatch Nuclear Plant: Unit 2	786,000	Georgia Power Co.	1976
ILLINOIS				
Morris	Dresden Nuclear Power Station: Unit 1	200,000	Commonwealth Edison Co.	1960
Morris	Dresden Nuclear Power Station: Unit 2	809,000	Commonwealth Edison Co.	1970
Morris	Dresden Nuclear Power Station: Unit 3	809,000	Commonwealth Edison Co.	1970
Zion	Zion Nuclear Plant: Unit 1	1,050,000	Commonwealth Edison Co.	1971
Zion	Zion Nuclear Plant: Unit 2	1,050,000	Commonwealth Edison Co.	1973
Cordova	Quad-Cities Station: Unit 1	809,000	Comm. Ed. Co.–Ia.–Ill. Gas & Elec. Co	1971
Cordova	Quad-Cities Station: Unit 2	809,000	Comm. Ed. Co.–Ia.–Ill. Gas & Elec. Co.	1971
Seneca	LaSalle Co. Nuclear Station: Unit 1	1,100,000	Comm. Ed. Co.–Ia.–Ill. Gas & Elec. Co.	1975
Seneca	LaSalle Co. Nuclear Station: Unit 2	1,100,000	Comm. Ed. Co.–Ia.–Ill. Gas & Elec. Co.	1976
INDIANA				
Dunes Acres	Bailly Generating Station	660,000	Northern Indiana Public Service Co.	1976
IOWA				
Cedar Rapids	Duane Arnold Energy Center: Unit 1	545,000	Iowa Electric Light and Power Co.	1973
MAINE				
Wiscasset	Maine Yankee Atomic Power Plant	790,000	Maine Yankee Atomic Power Co.	1972
MARYLAND				
Lusby	Calvert Cliffs Nuclear Power Plant: Unit 1	800,000	Baltimore Gas and Electric Co.	1973
Lusby	Calvert Cliffs Nuclear Power Plant: Unit 2	800,000	Baltimore Gas and Electric Co.	1974
MASSACHUSETTS				
Rowe	Yankee Nuclear Power Station	175,000	Yankee Atomic Electric Co.	1961
Plymouth	Pilgrim Station	654,000	Boston Edison Co.	1971
MICHIGAN				
Big Rock Point	Big Rock Point Nuclear Plant	70,300	Consumers Power Co.	1963
South Haven	Palisades Nuclear Power Station	700,000	Consumers Power Co.	1970
Lagoona Beach	Enrico Fermi Atomic Power Plant: Unit 1	60,900	Detroit Edison Co.	1963
Lagoona Beach	Enrico Fermi Atomic Power Plant: Unit 2	1,123,000	Detroit Edison Co.	1974
Bridgman	Donald C. Cook Plant: Unit 1	1,054,000	Indiana & Michigan Electric Co.	1972
Bridgman	Donald C. Cook Plant: Unit 2	1,060,000	Indiana & Michigan Electric Co.	1973
Midland	Midland Nuclear Power Plant: Unit 1	492,000	Consumers Power Co.	1973
Midland	Midland Nuclear Power Plant: Unit 2	818,000	Consumers Power Co.	1974
MINNESOTA				
Monticello	Monticello Nuclear Generating Plant	545,000	Northern States Power Co.	1970
Red Wing	Prairie Island Nuclear Generating Plant: Unit 1	530,000	Northern States Power Co.	1972
Red Wing	Prairie Island Nuclear Generating Plant: Unit 2	530,000	Northern States Power Co.	1974
NEBRASKA				
Fort Calhoun	Ft. Calhoun Station: Unit 1	457,400	Omaha Public Power District	1972
Brownville	Cooper Nuclear Station	778,000	Consumers Public Power District and Iowa Power and Light Co.	1972
NEW JERSEY				
Toms River	Oyster Creek Nuclear Power Plant: Unit 1	530,000	Jersey Central Power & Light Co.	1969
Lacey Township	Forked River Generating Station: Unit 1	1,129,000	Jersey Central Power & Light Co.	1975
Salem	Salem Nuclear Generating Station: Unit 1	1,050,000	Public Service Electric and Gas, N. J.	1972
Salem	Salem Nuclear Generating Station: Unit 2	1,050,000	Public Service Electric and Gas, N. J.	1973
Newbold Island	Newbold Nuclear Generating Station: Unit 1	1,088,000	Public Service Electric and Gas, N. J.	1975
Newbold Island	Newbold Nuclear Generating Station: Unit 2	1,088,000	Public Service Electric and Gas, N. J.	1977
NEW YORK				
Indian Point	Indian Point Station: Unit 1	265,000	Consolidated Edison Co.	1963
Indian Point	Indian Point Station: Unit 2	873,000	Consolidated Edison Co.	1971
Indian Point	Indian Point Station: Unit 3	965,000	Consolidated Edison Co.	1973
Scriba	Nine Mile Point Nuclear Station	500,000	Niagara Mohawk Power Co.	1969
Rochester	R.E.Ginna Nuclear Power Plant: Unit 1	420,000	Rochester Gas & Electric Co.	1970
Brookhaven	Shoreham Nuclear Power Station	819,000	Long Island Lighting Co.	1975
Lansing	Bell Station	838,000	New York State Electric & Gas Co.	1978
Verplanck	Verplanck: Unit 1	1,115,000	Consolidated Edison Co.	1977
Scriba	James A. Fitzpatrick Nuclear Power Plant	821,000	Power Authority of State of N.Y.	1973
NORTH CAROLINA				
Southport	Brunswick Steam Electric Plant: Unit 1	821,000	Carolina Power and Light Co.	1975
Southport	Brunswick Steam Electric Plant: Unit 2	821,000	Carolina Power and Light Co.	1976
*		821,000	Carolina Power and Light Co.	—
Cowans Ford Dam	Wm. B. McGuire Nuclear Station: Unit 1	1,150,000	Duke Power Co.	1975
Cownas Ford Dam	Wm. B. McGuire Nuclear Station: Unit 2	1,150,000	Duke Power Co.	1977
OHIO				
Oak Harbor	Davis-Besse Nuclear Power Station	872,000	Toledo Edison-Cleveland Electric Illuminating Co.	1974
Moscow	Wm. H. Zimmer Nuclear Power Station: Unit 1	810,000	Cincinnati Gas & Electric Co.	1974
Moscow	Wm. H. Zimmer Nuclear Power Station: Unit 2	810,000	Cincinnati Gas & Electric Co.	1975
OREGON				
Rainier	Trojan Station	1,106,000	Portland General Electric Co.	1974
PENNSYLVANIA				
Peach Bottom	Peach Bottom Atomic Power Station: Unit 1	40,000	Philadelphia Electric Co.	1967
Peach Bottom	Peach Bottom Atomic Power Station: Unit 2	1,065,000	Philadelphia Electric Co.	1971
Peach Bottom	Peach Bottom Atomic Power Station: Unit 3	1,065,000	Philadelphia Electric Co.	1973
Pottstown	Limerick Generating Station: Unit 1	1,065,000	Philadelphia Electric Co.	1975
Pottstown	Limerick Generating Station: Unit 2	1,065,000	Philadelphia Electric Co.	1977
Shippingport	Shippingport Atomic Power Station: Unit 1	90,000	Duquesne Light Co.	1957
Shippingport	Beaver Valley Power Station: Unit 1	847,000	Duquesne Light Co.–Ohio Edison Co.	1973
Middletown	Three Mile Island Nuclear Station: Unit 1	810,000	Metropolitan Edison Co.	1971
Middletown	Three Mile Island Nuclear Station: Unit 2	810,000	Jersey Central Power & Light Co.	1973
*	—	1,052,000	Pennsylvania Power and Light	1977
*	—	1,052,000	Pennsylvania Power and Light	1979
SOUTH CAROLINA				
Hartsville	H.B. Robinson S.E.Plant: Unit 2	700,000	Carolina Power & Light Co.	1970
Seneca	Oconee Nuclear Station: Unit 1	841,000	Duke Power Co.	1971
Seneca	Oconee Nuclear Station: Unit 2	886,000	Duke Power Co.	1972
Seneca	Oconee Nuclear Station: Unit 3	886,000	Duke Power Co.	1973
TENNESSEE				
Daisy	Sequoyah Nuclear Power Plant: Unit 1	1,124,000	Tennessee Valley Authority	1973
Daisy	Sequoyah Nuclear Power Plant: Unit 2	1,124,000	Tennessee Valley Authority	1974
VERMONT				
Vernon	Vermont Yankee Generating Station	513,900	Vermont Yankee Nuclear Power Corp.-Green Mt. Power Corp.	1971
VIRGINIA				
Gravel Neck	Surry Power Station: Unit 1	780,000	Virginia Electric & Power Co.	1971
Gravel Neck	Surry Power Station: Unit 2	780,000	Virginia Electric & Power Co.	1972
Mineral	North Anna Power Station: Unit 1	845,000	Virginia Electric & Power Co.	1974
Mineral	North Anna Power Station: Unit 2	845,000	Vriginia Electric & Power Co.	1975
WASHINGTON				
Richland	N-Reactor/WPPSS Steam	790,000	Washington Public Power Supply System	1966
WISCONSIN				
Genoa	LaCrosse Boiling Water Reactor	50,000	Dairyland Power Cooperative	1969
Two Creeks	Point Beach Nuclear Plant: Unit 1	497,000	Wisconsin Michigan Power Co.	1970
Two Creeks	Point Beach Nuclear Plant: Unit 2	497,000	Wisconsin Michigan Power Co.	1971
Carlton	Kewaunee Nuclear Power Plant: Unit 1	527,000	Wisconsin Public Service Co.	1972
PUERTO RICO				
Central Aguirre	Aguirre Nuclear Power Plant	583,000	Puerto Rico Water Resources Authority	1976

* Site not selected.

Figure 1. Nuclear Power Plants in the United States

NUCLEAR POWER PLANTS IN THE UNITED STATES

The nuclear power plants included in this map are ones whose power is being transmitted or is scheduled to be transmitted over utility electric power grids and for which reactor suppliers have been selected



NUCLEAR PLANT CAPACITY
(KILOWATTS)

OPERABLE		5,073,700
BEING BUILT		43,756,900
PLANNED	REACTORS ORDERED	32,591,000
	REACTORS NOT ORDERED	7,589,000
	TOTAL	89,010,600

ELECTRIC UTILITY CAPACITY BY CONVENTIONAL MEANS AS OF APRIL 30, 1970: 313,854,808 KILOWATTS

LEGEND

OPERABLE	■	(16)
BEING BUILT	▲	(54)
*PLANNED (Reactors Ordered)	●	(35)

*8 more plants have been announced for which reactors have not yet been ordered.

U.S. Atomic Energy Commission
June 30, 1970

Figure 1. Nuclear Power Plants in the United States—Continued

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

TRITIUM IN STREAMS IN THE UNITED STATES, 1961–1968. *T. A. Wyerman, R. K. Farmsworth,* and *G. L. Stewart. Radiological Health Data and Reports, Vol. 11, September 1970,* pp. 421–439.

As part of its program of water resources investigations, the U.S. Geological Survey. has been analyzing the tritium content of stream water since the early 1960's. The results of this sampling program for 20 streams in the conterminous United States and Alaska are tabulated along with relevant stream discharge data. The data show the effect on stream tritium concentration caused principally by thermonuclear detonations, and also seasonal, latitudinal, and continental effects.

KEYWORDS: Continental United States, stream discharge, tritium, water

NATURAL ENVIRONMENTAL RADIOACTIVITY IN SOUTH FLORIDA SANDS AND SOILS, FEBRUARY–JUNE 1968. *Douglas H. Keefer* and *Maxwell Dauer. Radiological Health Data and Reports, Vol. 11, September 1970,* pp. 441–448.

An investigation of the naturally occurring gamma-emitting radionuclides present in selected sands and soils of south Florida was conducted. Although the primary interest was in the natural environmental radioactivity from uranium-238, radium-226, thorium-232, and potassium-49, the concentrations of five fission products were also determined to minimize the error in computing the concentrations of the four naturally occurring radionuclides. The determination of these nine radionuclides in 45 environmental samples was performed by the linear least-squares method of analysis utilizing a computer.

KEYWORDS: Florida, potassium-40, radium-226, sands, soils, thorium-232, uranium-238

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